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THE UNIVERSAL LANGUAGE

BY RUFUS T. STROHM

NEARLY every power station owes its origin to men
Who expect the wealth invested to return to them again.
They are uninformed on technics, so that talk of B.t.u.'s,
CO_2 and kindred topics will but puzzle and confuse;
But they're clever at discerning how the cost of running trends,
And they show appreciation of substantial dividends.
Like as not they can't identify a gudgeon from a gland,
But the dollar talks a language that the owners understand.

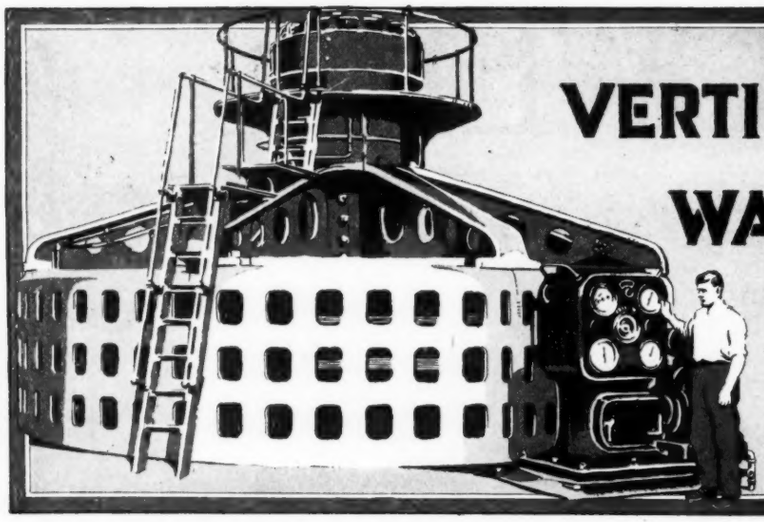
$

YOU have done your best to show them, in a mathematic way,
That you waste a lot of fuel through the ashpit every day,
And you've put the fact before them, just as plain as you can state,
That the economic method is to change the style of grate;
But their hearts are unresponsive and their eyes are hard and cold
Till you render the percentage of the saving into gold.
That's the sort of solar plexus that will never fail to land,
For the dollar talks a language that the owners understand.

YOU have doubtless had occasion to remind them of the need
Of a modern form of heater in connection with the feed,
And you've found that all your efforts were a simple waste of breath,
For their ears were deaf as marble and their lips were still as death.
So, suppose you change your tactics; jar their chill indifference
By translating facts and figures into quarters, dimes, and cents,
And they'll carry out your changes in the way that you have planned,
For the dollar talks a language that the owners understand.

$

IF a lessening of labor is the ground on which you rest
In the scheme of alterations or additions you suggest,
It is probable they'll bluster, and it's safe to say they'll growl,
And they'll meet your chain of logic with a fierce, forbidding scowl;
But their icy glance will soften and the frost will disappear
If you state how many shekels you can save them in a year,
And before you know what's doing, they'll be feeding from your hand,
For the dollar talks a language that the owners understand.



VERTICAL-SHAFT WATER-WHEEL ALTERNATOR

BY H. D. STEPHENS

Waterwheel-driven alternators may be classed under two types, vertical and horizontal. In this article the author describes the general construction, the thrust bearing, methods of lubrication and different schemes employed to drive the exciter, for the vertical type.

THE scarcity of coal which we have been experiencing has emphasized, perhaps as no other agency could, the urgent need for conservation of our natural resources, and action favorable to water-power development has been asked of Congress by President Wilson, and may therefore be hoped for in the near future.

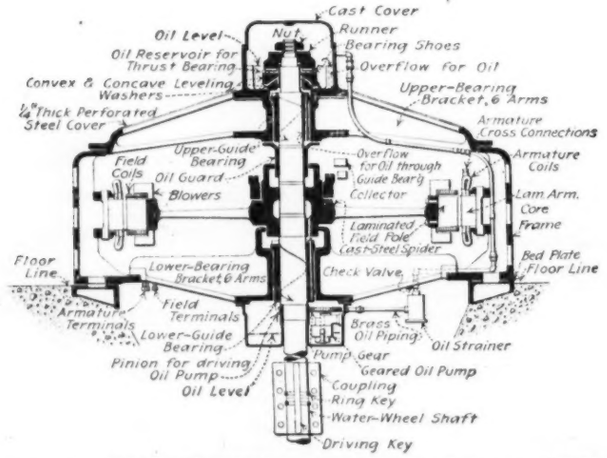


FIG. 1. CROSS-SECTIONAL VIEW OF VERTICAL WATER-WHEEL GENERATOR

With the prospect of considerable activity in water-power development during the next few years, the marked tendency toward a more universal adaptation of the vertical type of unit is of interest. Because of the high efficiencies obtained with the single-runner, vertical-shaft waterwheel, the simplicity of power-house layout and flexibility, as regards station-floor levels, permitted by its use, this type of prime mover becomes the logical choice for most low-head and for many high-head installations.

The vertical type cannot strictly be considered a new one, for it was used in the earliest developments at Niagara Falls; but it has only been within the last decade, and in fact since the advent of the high-efficiency, vertical, single-runner wheel, that its application has been seriously considered, if not actually adopted, for a majority of installations. Despite a very limited activity in hydro-electric work during most of this period, sufficient development has been going on to allow manufacturers and operators to work out those mechanical problems peculiar to the vertical unit to the satisfaction of both. While the wide range of capacity and speed encountered prohibits any absolute standardization of construction, the general problems of bearing supports, lubrication, etc., are common to all sizes, and the general standards resulting from a wide experience in this field are worthy of note. The information contained in the following paragraphs deals mainly with the product of the Westinghouse Electric and Manufacturing Company.

A typical cross-sectional view of a vertical generator is shown in Fig. 1, which covers a self-contained machine; that is, one with thrust bearing mounted on top of the generator, an upper and a lower guide bearing, one above and the other below the rotor, and arranged for connection to the waterwheel by means of a "muff" coupling. Most of the structural details of this type of unit are indicated in Fig. 1. The stationary frame extends, at both top and bottom, beyond the active section of the stator core a sufficient distance to form an adequate protection for the end turns of the armature winding. The cross-connections and wiring on the armature winding are on the upper side of the stator for convenience should any repairs after the initial installation be required. The leads from the armature and field and all the oil piping are ordinarily brought down just inside the stator frame in order to protect from possible injury.

Probably the most troublesome problem in early days involved the location of the thrust bearing. If this were mounted below the waterwheel, it was very inaccessible and therefore difficult to keep in repair. Mounted between the waterwheel and the generator, it usually required a special floor and therefore added expense to the cost of the power plant. It was finally

decided to put this bearing on top of the generator, as shown in Fig. 1, and today practically all units being built are arranged in this manner. For a long time the thrust bearing itself was a matter of considerable concern. However, the introduction of the Kingsbury bearing has gone a long way toward eliminating, by its almost universal success over a wide range of capacity, the feeling of distrust of the vertical

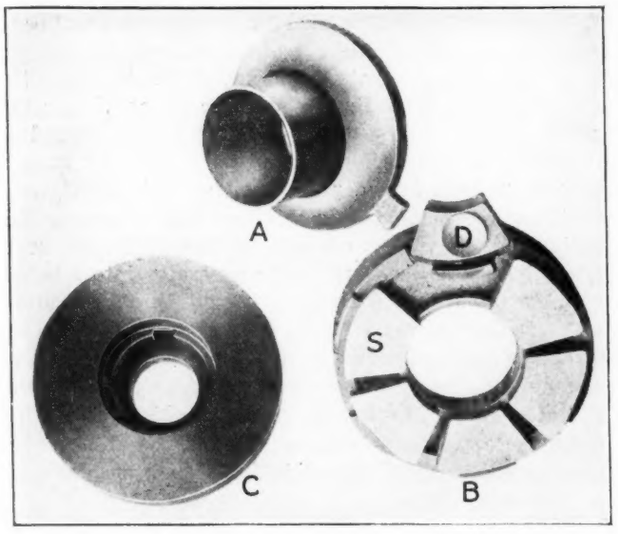


FIG. 2. PARTS OF KINGSBURY THRUST BEARING

unit on this account. The detail of this type of thrust bearing is shown in Fig. 2. The bearing runs in a bath of oil, has exceedingly small frictional losses and therefore a low-temperature rise in service, and no appreciable wear.

As shown in the figure, the bearing consists essentially of three parts. *A* and *B* are what may be termed the convex and concave leveling washers, and *C* the runner; all three parts are contained in an oil-tight bearing housing and are shown at the top of Fig. 1. It will be seen that part *A* acts as a supporting casting to carry the entire weight of the revolving element. The concave surface on the lower side of part *B* rests on the spherical surface of part *A* to allow the proper alignment of the bearing. On the upper surface of part *B* are mounted a number of shoes *S*. Each shoe is babbitted on its upper surface and rests on a spherical seat on its lower surface, which in turn allows it to tip slightly when in operation. One of the shoes is shown turned over in Fig. 2 to show the spherical seat *D*. The runner *C* is a special casting which is securely fastened to the rotating shaft and rests on the shoes *S*, which tips slightly when the runner is revolving and allows a wedge-shaped film of oil to form between the runner and shoes.

There are four, six or eight shoes to a bearing, depending upon its size and the weight it has to carry. There is no direct contact between the shoes and the revolving runner except when the machine is at rest, and it has actually been found in practice that small tool marks on the babbitt surface exist for many months after the bearing has been in use. In other words, no appreciable wear can be detected.

The thrust bearing is called upon to carry heavy loads, from 300,000 to 400,000 lb. with the larger-capacity units, this being due to supporting not only the weight of the rotating element of the generator proper, all the shafting and the waterwheel runner, but also the unbalanced or downward force of the water which flows through the wheel when in service.

This necessitates an exceptionally sturdy frame and a heavy upper bracket having no appreciable deflection. A bracket with a number of I-beam section arms spaced equidistant around the periphery of the stator frame and bolted thereto has filled the requirements admirably and is now almost universally used (see headpiece and Fig. 3).

The bracket that supports the thrust bearing also carries a guide bearing, Fig. 1, whose function it is to center the rotor in the middle of the stationary part. This bearing is babbitt-lined. Immediately beneath the rotor a bracket similar to that used for supporting the thrust and upper-guide bearing is employed. This is also bolted to the stator frame, as in Fig. 1. Ordinarily, this bracket is employed only to house the lower-guide bearing, which is babbitt-lined, but in many cases, particularly with large-capacity units, it must be strong enough to support the rotor during dismantling, and in those cases where braking is necessary.

It has been found, particularly in many low-head installations, that the gates that shut off the water have sufficient leakage through them even when closed to cause the rotor to operate at a very slow speed and thus to endanger the thrust bearing. To prevent damage in such cases, suitably machined pad supports are provided on the lower-bracket arms to mount brakes or jacks. These brakes can be operated so as to bear

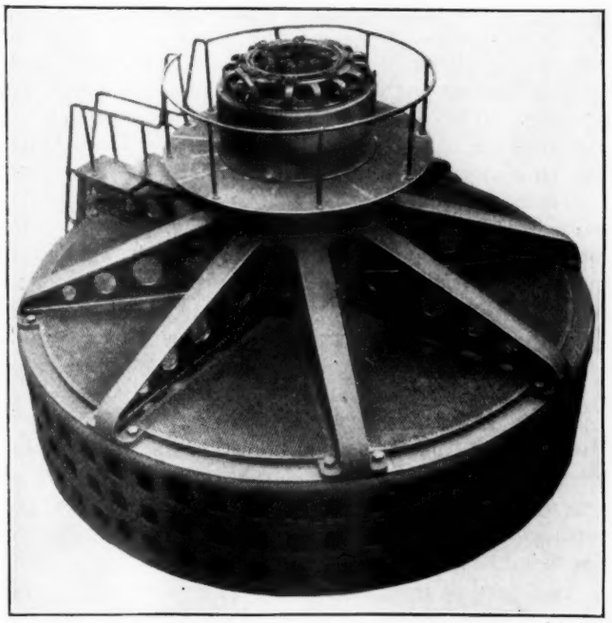


FIG. 3. VERTICAL ALTERNATOR, SHOWING I-BEAM METHOD OF SUPPORTING THRUST BEARING

upon a machined surface or circular plate on the rotor, to quickly bring the rotor to rest. To the lower bracket is also bolted an oil pan to catch the drain from the thrust bearing and from the two guide bearings.

Ordinarily, there is a break between the generator and the waterwheel shaft, as the mounting of the waterwheel runner on an extension of the generator shaft would

involve considerably more headroom for installation and dismantling for repairs than would otherwise be required. The advantages to be gained by the use of a common shaft seldom compensate for the increased power-plant cost; therefore separate shafts are used. Connection between the two is made by either a "clamp" or "muff" type coupling, in which two machined pieces

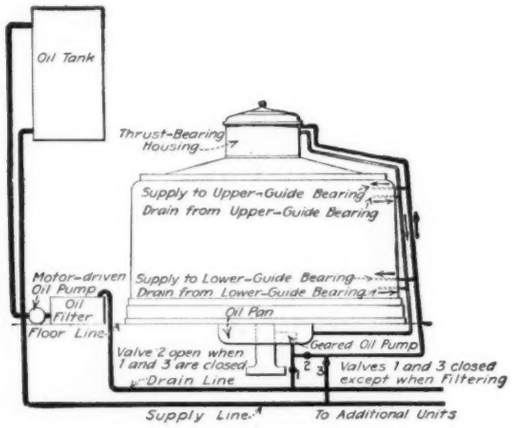


FIG. 4.—DIAGRAM OF SEPARATE OILING SYSTEM

are bolted and keyed over the ends of the two shafts, or half-couplings forged directly on the generator and waterwheel shafts and the two connected rigidly together by bolts, are employed.

There are some cases, where the distance between the generator and the waterwheel runner is very small, in which the lower-guide bearing can readily be eliminated. Two different types of bearings are ordinarily used on the generator and on the waterwheel. The generator bearing is a babbitt-lined one, and any appreciable wear of the bearing surface is likely to cause vibration and trouble. The waterwheel bearing is ordinarily of lignum-vitæ blocks lubricated by water. These blocks are in a more or less inaccessible place and are rarely inspected or repaired. They can wear quite appreciably without causing serious trouble. When the generator has two bearings, these will often maintain true alignment even with considerable looseness around the waterwheel bearing. When only two bearings are employed, however, one on the generator and one on the waterwheel, any wear is found to immediately cause vibration and trouble. This, I believe, is the reason why it is so generally customary to employ the self-contained generator. It is somewhat questionable whether the danger has not been considerably exaggerated, since quite a number of installations have gone into service without a lower-guide bearing, and such installations are operating very satisfactorily.

Two general methods of lubrication for vertical machines are employed. On a machine where the flow of oil to the thrust and guide bearings does not exceed three or four gal. per min., a self-contained system, as shown in Fig. 1, is employed. The oil, from the pan bolted to the lower-guide-bearing bracket, is forced through brass piping by a small pump, gear driven from the main-generator shaft, as indicated. It flows through an oil strainer and then up into the housing holding the thrust bearing. Here provision for an adequate supply of oil for the guide bearings is made, and for the overflow. The drain from all bearings then flows back again into the lower oil pan. It is found that where the required amount of oil does not exceed the quantity specified, the oil is cooled sufficiently by radiation and no further means need be provided for cooling. As the system is an entirely closed one, there is little likelihood of dust or dirt getting into the oil, and operation for long periods of time without renewal is to be expected.

Where the weight carried by the thrust bearing is very heavy and where considerable quantities of oil are required, a separate oiling system is employed, the oil circulation through the machine proper being the same as that already described, except that instead of it returning and being pumped back into the system through a gear-driven pump on the main shaft, connections are made at the base of the generator for piping the oil into a common system. The oil flows from the pan at the base of the generator into a reservoir, from which it is pumped, usually through a filter, into a tank; from here the oil is returned to the various machines by means of gravity. Very considerable amounts of money can easily be spent on such a lubricating system. As the circuit is a closed one, it is not necessary to continuously filter all the oil from all the machines, and a filter having a much smaller con-

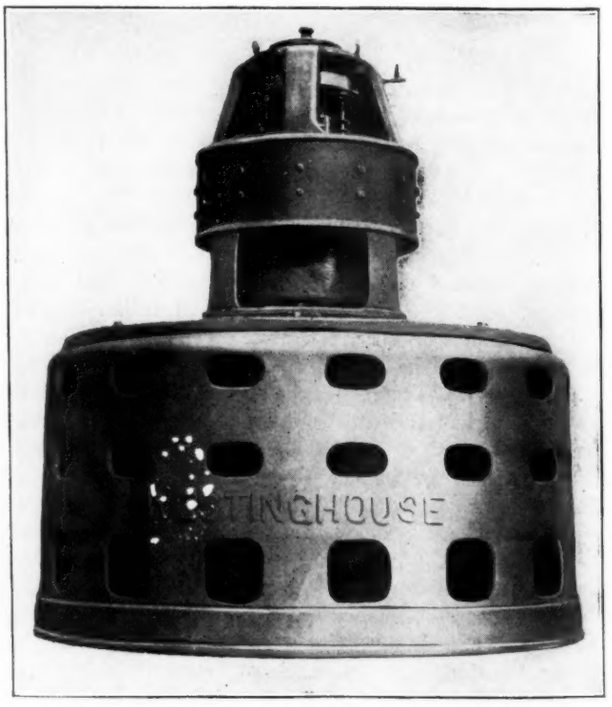


FIG. 5. VERTICAL WATERWHEEL ALTERNATOR WITH EXCITER MOUNTED ON TOP OF MACHINE

tinuous capacity can safely be installed. Cooling of the oil in the larger systems is usually accomplished by a flow of water through a coil of pipe placed in the reservoir or tank.

A system that is relatively inexpensive and that can be installed where several units of small capacity are employed, is shown in Fig. 4. Ordinarily, the oil flows through the closed system of each individual machine, but at intervals when it is desired to filter the oil from

one unit, this is done by changing the valves shown and running the oil to be filtered through the filter into the supply tank. Brass piping throughout the entire supply system is preferable for the reason that such pipe does not corrode or rust.

By installing water-cooling coils in the thrust-bearing housing, very much the same effect can be gained as with the external-oiling system, as regards keeping the oil sufficiently cool for satisfactory service. While such methods are undoubtedly feasible, the water piping would necessarily take up a considerable space and therefore make the room normally available in the housing for inspection or repair very much congested. Furthermore, the carrying of water to the top of the generator, where a leak or break in the pipe during operation might result in considerable damage to the machine, is questionable.

The exciter problem, particularly with alternators that operate at slow speeds, is probably the most difficult of all the electrical ones in connection with the power-plant design, and the method that will combine maximum operating efficiency and minimum first cost and maintenance is found only after careful analysis.

Individual direct-connected exciters, as shown mounted on top of the machines, Figs. 3 and 5, should receive first consideration as giving the simplest and cheapest plan layout. In this consideration, however, certain fundamental facts concerning both alternating and direct-current generators appear: First, that the slower the speed of the alternator the greater is its per-

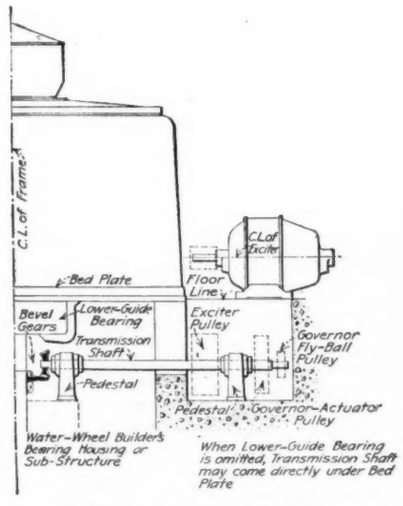


FIG. 6 GEAR- AND BELT-DRIVEN EXCITER

centage of excitation and the larger the exciter; second, that the slower the speed of the exciter the more expensive it is; third, that the slower the speed of the exciter the greater its field current and the more sluggish its operation, thus making the voltage regulator, now almost universally employed, both complicated and expensive. These factors may result in the direct-connected exciter being rejected on account of high first cost.

Where generator capacities are relatively small, individual high-speed exciters may still be employed, as shown in Figs. 6 and 7. Both methods have certain disadvantages, one in the introduction of the gear and the other in a quarter-turn belt. Either method, however, is fairly inexpensive, and both seem to give fairly satisfactory results.

Next, separate waterwheel exciters may be considered. Such units ought not to be excessive in cost, but may introduce considerable expense in connection with build-

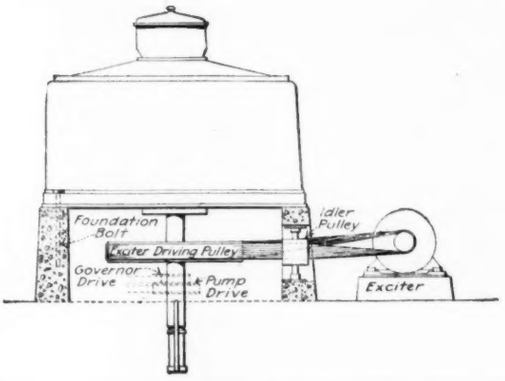


FIG. 7. QUARTER-TURN BELT-DRIVEN EXCITER

ing and wheel-pit costs. Also they may, because of the relatively small capacity of the wheel, require special and more expensive trash racks, etc.

A method often used is a combination of waterwheel driven and motor-driven sets, the exciter driven by the waterwheel being used for starting the plant and as a spare, and high-speed motor-generator sets furnishing the excitation normally.

Any one of the foregoing methods may be considered as fairly standard, and the choice, of course, depends on the number of main units in the plant, relative costs of each method, conditions of operation more or less peculiar to the individual plant, etc. In general, it may be stated that the larger the capacity of the separate generating units and the higher their speed, the more favorable becomes the indivdual direct-connected exciter layout.

Heat Transfer

Radiation of heat takes place between bodies at all distances apart. Heat rays proceed in straight lines, and the intensity of the rays varies inversely as the square of their distance from the source.

Conduction is the transfer of heat between two bodies or parts of a body which touch each other. Internal conduction takes place between the parts of one continuous body and external conduction through the surface of contact of a pair of distinct bodies. The conduction of heat through a stagnant mass is very slow in liquids and almost, if not wholly, inappreciable in gases. It is only by the continual circulation and mixture of the particles of fluid that uniformity of temperature can be maintained in the fluid mass, or heat transferred between the fluid and a solid body.

Convection, conveying or carrying of heat means the transfer or diffusion of heat by means of the motion of the mass.

Where are the spendthrifts of yesteryear? Buying Liberty Bonds. The air of liberty, they find, is better than champagne, and the effect lasts longer.

Stoker Capacity vs. Boiler Forcing Rates

By JOSEPH T. FOSTER*

This article suggests ways in which the plant owner can check his boiler performance against any well-defined standard and ascertain what improvements will result if certain changes are effected.

EVERY central station and plant operating boilers and prime movers is striving, or at least should strive to do two things: To get the maximum output from existing equipment without loss of time or expenditure of money for extensive rearrangement and to eliminate every possible item of waste, particularly the waste of coal, not only because of its present high price, but also because of the diminution in the available supply. From present indications the need for economy will not cease with the war, as the ensuing period will be one of readjustment and will probably be accompanied by high operating costs in every branch of industry.

Many companies have their boilers equipped with instruments to give data on boiler performance and conduct boiler tests at intervals for the purpose of showing up any abnormal conditions. The usual boiler test is susceptible of a certain amount of analysis, and it is possible to tell whether the boiler performance was good or only fair under the conditions of test, but it

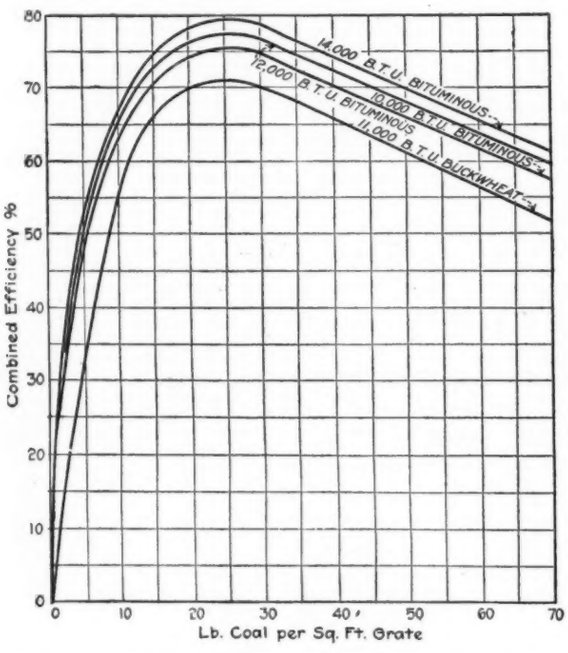


FIG. 1. RELATION BETWEEN COMBINED EFFICIENCY AND COAL BURNED PER SQUARE FOOT OF GRATE

does not tell whether a boiler is doing its best day after day. There seems to be no way in which the plant owner can survey the whole situation, check his boiler performance against any well-defined standard and ascertain what improvement might be realized if certain changes were made. It is the purpose of this article to supply such a standard and to suggest ways to compare a given performance with the best. Predictions as to economical forcing rates for boilers have been based chiefly on the square feet of heating surface without sufficient regard to the square feet of grate surface or the pounds of coal burned per square foot.

It is difficult to see why variation in efficiency should be so commonly referred to square feet of heating surface or, what amounts to the same thing, to the percentage of the nominal rating. When a boiler is properly designed as regards heating surface, efficiency is a function of the furnace conditions only, and these are in turn dependent on the number of square feet of grate. Recently the tendency has been to give proper attention to this phase of the matter, and larger grate

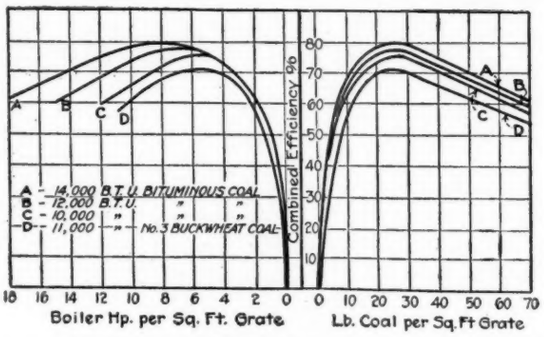

A - 14,000 B.T.U. BITUMINOUS COAL
B - 12,000 B.T.U. " "
C - 10,000 " " "
D - 11,000 " No. 3 BUCKWHEAT COAL
Combined Efficiency %
Boiler Hp. per Sq. Ft. Grate
Lb. Coal per Sq. Ft. Grate

FIG 2. COMBINED EFFICIENCIES AT VARIOUS STOKER FORCING RATES

areas are becoming more common. A larger grate means a larger volume of hot gases and, by the moving back of the bridge-wall, a larger amount of tube surface exposed to the direct radiation from the fuel bed. The gain is therefore twofold.

Formulas have been developed for computing combined efficiencies at various forcing rates, but such formulas are based on heating surface and the results obtained from them are empirical for a given size and type of grate. The efficiency formulas were of greater service some ten years ago, when there was a more definite relation between heating surface and grate surface. A definite relation existed then because with hand firing the depth of grate was limited by the ability of the fireman to handle the coal, and 6- or 6½-ft. grates were the rule. With a definite ratio between heating surface and grate surface the empirical formula developed for one set of conditions could be applied to other conditions with some degree of accuracy. B.t.u. input is certainly the governing factor in boiler output, and since the heat input is directly dependent on the amount of grate surface, this surface is the datum from which calculations should be made.

Boiler tests prove that the plotting of combined efficiency against the pounds of coal burned per square foot of grate surface shows a characteristic curve which has a definite form regardless of the character of the fuel or the size of the boiler. Fig. 1 shows the form of curves derived from actual tests. The curves for bituminous coal were obtained from tests on a battery

*Public Service Electric Company, Newark, N. J.

of 1400 rated horsepower boilers and the curve for the buckwheat is a composite from numerous tests on boilers varying in capacity from 1000 to 250 hp. It will be noticed that the curves have the same general characteristics even though boiler capacities and kind of fuel varied widely. All grades show best efficiency at a rate of about 25 lb. of coal per square foot of grate surface per hour. Boiler-heating surface seems to have

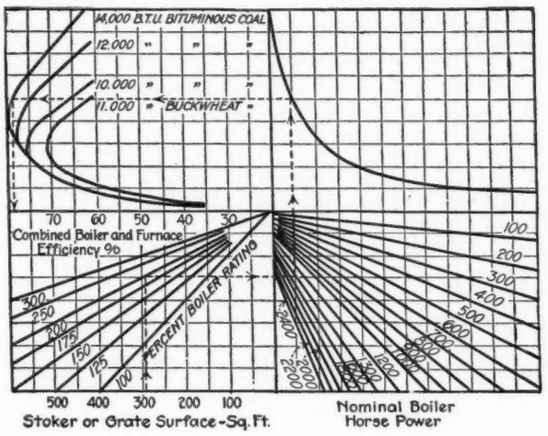

14,000 B.T.U. BITUMINOUS COAL
12,000 " " "
10,000 " " "
11,000 " BUCKWHEAT "
Combined Boiler and Furnace Efficiency %
PERCENT BOILER RATING
Stoker or Grate Surface-Sq. Ft.
Nominal Boiler Horse Power

FIG. 3. RELATION OF BOILER HORSEPOWER PERCENTAGE RATING, GRATE SURFACE AND EFFICIENCY

been pretty definitely fixed at 10 sq.ft. per nominal horsepower, and on this basis the curve will be of value in predicting efficiencies at various forcing rates.

Fig. 2 is a combined curve showing efficiencies plotted against pounds of coal per square foot of grate per hour and boiler horsepower per square foot of grate. The effect of the burning qualities of the fuel on the output is very marked. The most economical forcing rate for the 14,000-B.t.u. coal is 9 boiler horsepower per square foot of grate and for the buckwheat 6 hp. There is also a difference of approximately 10 per cent. between the best efficiencies realized.

Fig. 3 is a chart worked out on the basis of test results and shows the relation between combined efficiency and grate surface for various sizes of boilers under different operating conditions and with different kinds of fuel.

Example 1: What efficiency will be obtainable with a 1400-hp. boiler having 290 sq.ft. of grate surface when operated at 200 per cent. rating with 14,000 B.t.u. coal?

Solution: Project upward from 290 sq.ft. of grate surface to the 200 per cent. rating line, then horizontally to the right to the 1400 nominal horsepower line, then vertically to the curved transfer line and horizontally to the left to the point of intersection with the efficiency curve, thence vertically downward read the efficiency as 78.5 per cent.

Example 2: A boiler with a nominal rating of 1000 hp. and having 350 sq.ft. of grate surface is being operated at 150 per cent. rating on 12,000-B.t.u. coal. Is it developing its best efficiency, and if not, at what rating should it be run?

Solution: Following out the method outlined, it will be seen that the boiler is developing 73.5 per cent. efficiency. The best efficiency with this coal is 77.5 per cent. Reversing the operation by projecting horizontally from the point of best efficiency of the curve for 12,000-B.t.u. coal to the transfer line, downward to the nominal rating curve, horizontally to a vertical line from 350 sq.ft., read 230 per cent. as the rating at which to operate the boiler for maximum efficiency. Where a number of boilers are on the line operating under the conditions in the second example, it would be possible to cut out one or more boilers with a large fuel saving on account of the increased efficiency of the remaining boilers at the higher rate of steaming.

The practical use of this method will be recognized and the following instance is a case in point: The initial installation in a certain plant consisted of a battery of boilers with 221 sq.ft. of grate surface and rated at 1400 hp. and operated at 79 per cent. efficiency when developing 145 per cent. rating, burning 14,000-B.t.u. coal. Increased load on the plant required a second installation, and it was desirable that it should develop its best efficiency at a higher rating. It was therefore designed with a grate surface of 291 sq.ft. and will develop 79 per cent. efficiency at approximately 200 per cent. rating. It is much cheaper to develop greater horsepower by means of larger grates than by increasing the boiler-heating surface, for large heating surface involves high initial cost not only of the boilers themselves, but of all the other items entering into their erection. Where cubic feet of available space in the boiler house is limited, the question of grate surface is of importance because every unnecessary cubic foot taken up by the boilers means a higher plant cost. The question of grate area, however, is not limited to new plants, but is of equal importance where the boilers are

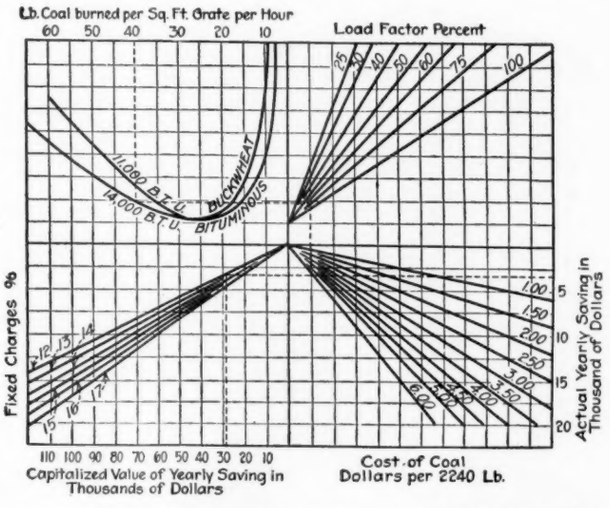

Lb. Coal burned per Sq. Ft. Grate per Hour
Load Factor Percent
11,000 B.T.U. BUCKWHEAT
14,000 B.T.U. BITUMINOUS
Fixed Charges %
Actual Yearly Saving in Thousand of Dollars
Capitalized Value of Yearly Saving in Thousands of Dollars
Cost of Coal Dollars per 2240 Lb.

FIG. 4. CAPITALIZED VALUE OF SAVING REALIZED BY OPERATING AT BEST FORCING RATE

already installed. Where the grate surface is found to be too small, it would be profitable in almost every instance to spend the money necessary to enlarge it.

Fig. 4 is designed to show in dollars the saving which will result from changing from a given condition to the best condition, as shown in Fig. 1; namely, 25 lb. of coal burned per square foot of grate per hour, for various load factors and coal prices. The value of the annual saving, capitalized at from 12 to 17 per cent., is also given. All values are calculated for a 1000-hp. load, the data for other loads being proportionate. Only two grades of coal are shown in this chart, but other grades, since they fall between the two, can readily be

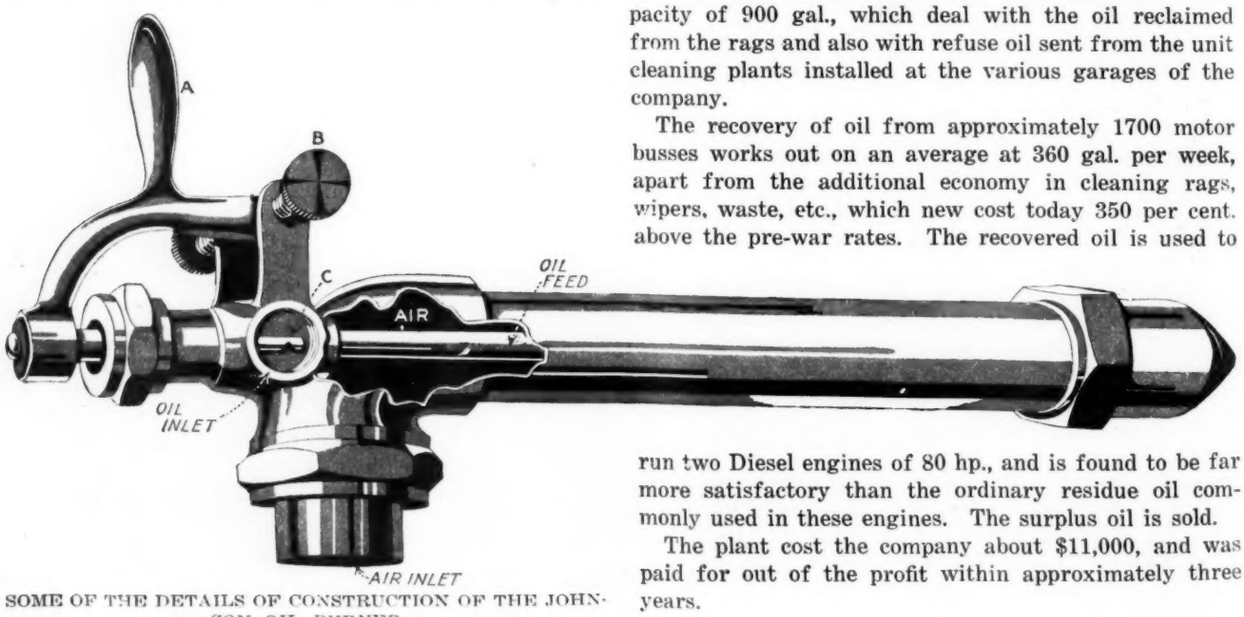
interpolated. Example: A boiler is being forced so that 40 lb. of coal is burned per hour per square foot of grate. What saving would be realized yearly if the forcing rate were brought down to the foregoing standard, 25 lb. per sq.ft. per hour, or the most economical value? How much money could be profitably spent for additional boiler capacity to bring about this result if coal is $6 per ton and the saving is capitalized at 12 per cent., and 75 per cent. is the assumed load factor?

Solution: Project downward from 40 lb. the coal burned per hour per square foot of grate to intersect with the 14,000-B.t.u. curve, then horizontally to the right to the 75 per cent. load factor line, then vertically down to the cost of coal per ton, $6. From this point horizontally read on the right-hand scale the yearly saving, $3250, or horizontally to the left to the 12 per cent. line and vertically downward read the capitalized value, $28,000, the amount that could profitably be spent for additional boiler capacity.

The application of the curves is not confined to problems covering boilers already equipped, but can be used equally well for calculating the saving that would result in some cases from the use of stokers on hand-fired boilers. Assuming hand-fired boilers in which a rate of eight pounds of coal per square foot of grate per hour is maintained, the boiler efficiency would be approximately 60 per cent. With a stoker that will burn 25 lb. per sq.ft. per hour, the capitalized value of the stoker can be read from the curves in the same manner as described in the foregoing examples.

Johnson Crude Oil Burner

There are sections throughout the United States where crude oil is preferable to coal as a fuel under both heating and power boilers. In competition with coal 130 gal. of the cheapest grade of California fuel oil, containing about 18,500 B.t.u. per lb., is equal in heating value to one ton (2000 lb.) of the best grade of soft coal. In burning crude oil a burner of proper construction must be used.



SOME OF THE DETAILS OF CONSTRUCTION OF THE JOHNSON OIL BURNER

A low-pressure air crude-oil burner manufactured by the S. T. Johnson Co., Grace and Lowell Sts., San Francisco, Calif., has been developed to burn any kind of thick or thin oil, or oil containing water in emulsion.

Referring to the illustration, the burner is designed to vaporize heavy crude oil with an air pressure of between 1 and 5 lb. The burner has a 1-in. air connection and a ¾-in. oil connection and is furnished with an angle-ported valve *C*, which closely regulates the supply of oil to the furnace. The control of the flame is obtained by the adjustment of the lever *A*, which is locked into position by the two thumb-screws *B*. Oil is fed to the burner nozzle through the pipe opening shown, and the air supply going through the nozzle head surrounds the oil pipe. The oil and air are mixed at the head, and the flame is produced close to the tip of the burner.

Where air pressure is not available, a pressure blower is used, which furnishes the necessary air to atomize the oil without heating it before it reaches the burner.

Rag Washing and Oil Reclaiming

The London General Omnibus Co., Ltd., London, England, has, for about three years, been working a central recovery plant for reclaiming the oil and grease absorbed in rags, which so washes the cleaning material itself that it can be used over many times.

The depot is situated at Riley St., Chelsea, S. W., and the plant consists of a horizontal return-tubular boiler, three centrifugal steam-driven oil extractors, two hydro-extractors, three rotary washing machines and one rotary drying machine, together with a calender and an ironing machine to deal with the washing and pressing of women's overalls. The plant, in effect, is a typical laundry-machinery equipment.

In connection with this plant there are three steam-heated, oil-cleansing or settling tanks, each with a capacity of 900 gal., which deal with the oil reclaimed from the rags and also with refuse oil sent from the unit cleaning plants installed at the various garages of the company.

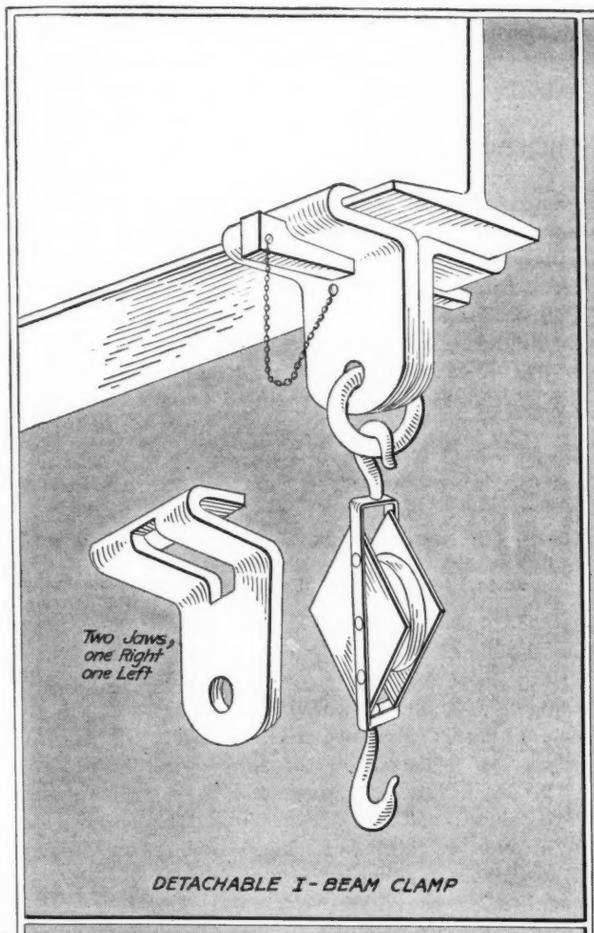
The recovery of oil from approximately 1700 motor busses works out on an average at 360 gal. per week, apart from the additional economy in cleaning rags, wipers, waste, etc., which new cost today 350 per cent. above the pre-war rates. The recovered oil is used to run two Diesel engines of 80 hp., and is found to be far more satisfactory than the ordinary residue oil commonly used in these engines. The surplus oil is sold.

The plant cost the company about $11,000, and was paid for out of the profit within approximately three years.

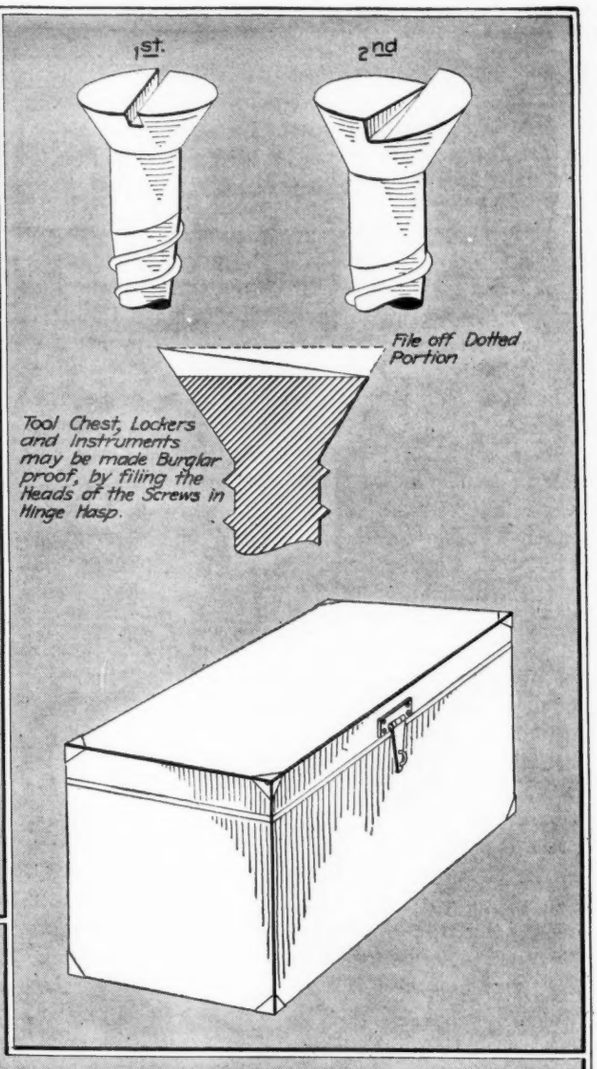
Liberty bondholders are justly another Grand Army of the Republic. You should lose no time in becoming a member of so glorious an army, even if you have purchased bonds in the other loans.

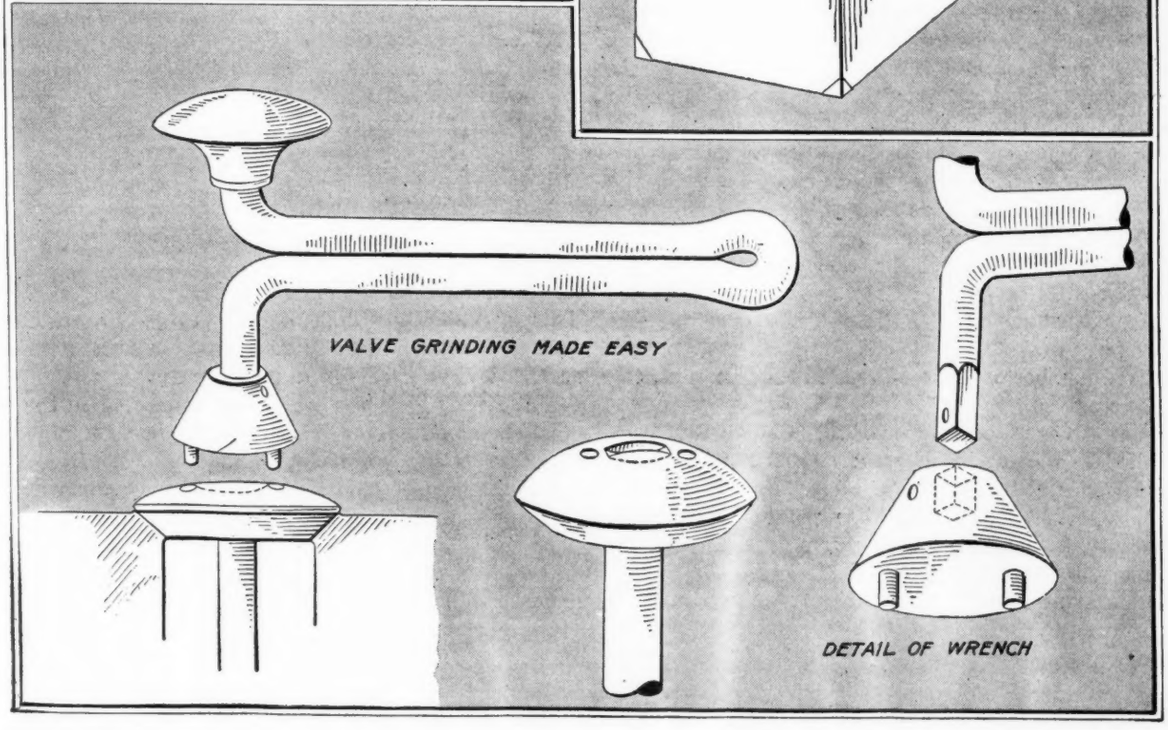
From an Engineer's Notebook

By M. P. Bertrande



DETACHABLE I-BEAM CLAMP


1st.
2nd
File off Dotted Portion
Tool Chest, Lockers and Instruments may be made Burglar proof, by filing the Heads of the Screws in Hinge Hasp.



The Electrical Study Course—Series-Connected Generators

A comparison is made between the shunt and series type of direct-current generators, showing how the voltage of the shunt type remains practically constant with different load values, while the voltage of the series varies with the load.

IN THE previous lesson we saw how a shunt generator was capable of building up a voltage from the residual magnetism in the fieldpoles when the field coils are connected to the armature in the proper relation, as in Fig. 1. In this case the field coils are connected across the armature, therefore the latter is capable of causing a current to flow through the former whether the armature is supplying an external load or not. In Fig. 1 the field circuit is from the positive brush through the field coils back to the negative brush without passing through terminals M and N, which lead to the external load, hence it is evident that the field circuit is independent of the load circuit.

In the series-connected generator, as in Fig. 2, it will be seen by following around from the brush marked plus through the field coils that in order for the circuit through the armature and field coils to be completed an external load L must be connected between terminals M and N, as in Fig. 3. In other words, the series generator cannot build up its voltage unless it is connected to a load.

Since the field coils of the series generator are connected in series with the load and armature, it is at once evident that the cross-section of the conductors in the field coils must be large enough to take care of the full-load current of the machine. The field coils on the shunt generator are connected across the armature and are wound with wire of a size that will make the coils of such a proportion as to produce the flux in the polepieces with the minimum expenditure of energy. The power required to excite the field coils is generally from about 1 to 3 per cent. of the output of the machine.

To generate a given voltage, the armature must revolve at a certain speed and the magnetic field of the polepieces must have a definite value. To set up the lines of force in the magnetic circuit, it is necessary that a required number of ampere-turns in the field coils, say 6000, be supplied.

Ampere-turns is the number of turns in a coil of wire multiplied by the current in amperes that flows through it when connected to an electric circuit; that is, if a coil contains 2000 turns and when connected to a 110-volt circuit, 3 amperes flow through it, then the ampere-turns are $2000 \times 3 = 6000$.

If we assume the machine in Fig. 1 to require 6000 ampere-turns to excite the field coils sufficiently for the armature to generate 110 volts, and further assume that the full-load current of the machine is 100 amperes and requires 3 amperes to excite the field coils, then the number of turns in the field coils will be ampere-turns divided by amperes, or $6000 \div 3 = 2000$, and the resistance of the wire in the field coils is volts divided by current, or $110 \div 3 = 37$ ohms approximately.

If the series machine, Fig. 3, is assumed to have the same capacity as the shunt machine, Fig. 1, and requires the same number of ampere-turns to excite the field coils as the shunt machine to generate 110 volts, then the number of turns of wire required in the field coils, since the total current is flowing through the field winding, will be $6000 \div 100 = 60$ turns, or 30 turns on each coil. Since the total current flows through the field coils and load in series, the combined resistance of the field coils and load can only be volts $\div$ amperes, or in this case, $110 \div 100 = 1.1$ ohms.

Now if we are to keep the amount of power expended in the field coils on the series machine down to approximately that of the shunt machine, or 3 per cent., then the resistance of the field coils can be only 3 per cent. of the total resistance, or $1.1 \times 0.03 = 0.033$ ohm, or the resistance of the field coils in the shunt machine is $\frac{37}{0.033} = 1121$ times that of the series machine. Herein lies the most prominent structural difference between the shunt and series type of machines. The field coils on the shunt machine are wound with a large number of turns of small wire having a comparatively high resistance and are connected in parallel with the armature. The field coils of the series machine are wound with a small number of turns of large wire, consequently have a low resistance and are connected in series with the armature. However, the size of the conductors in either case varies with the size and the voltage of the machine.

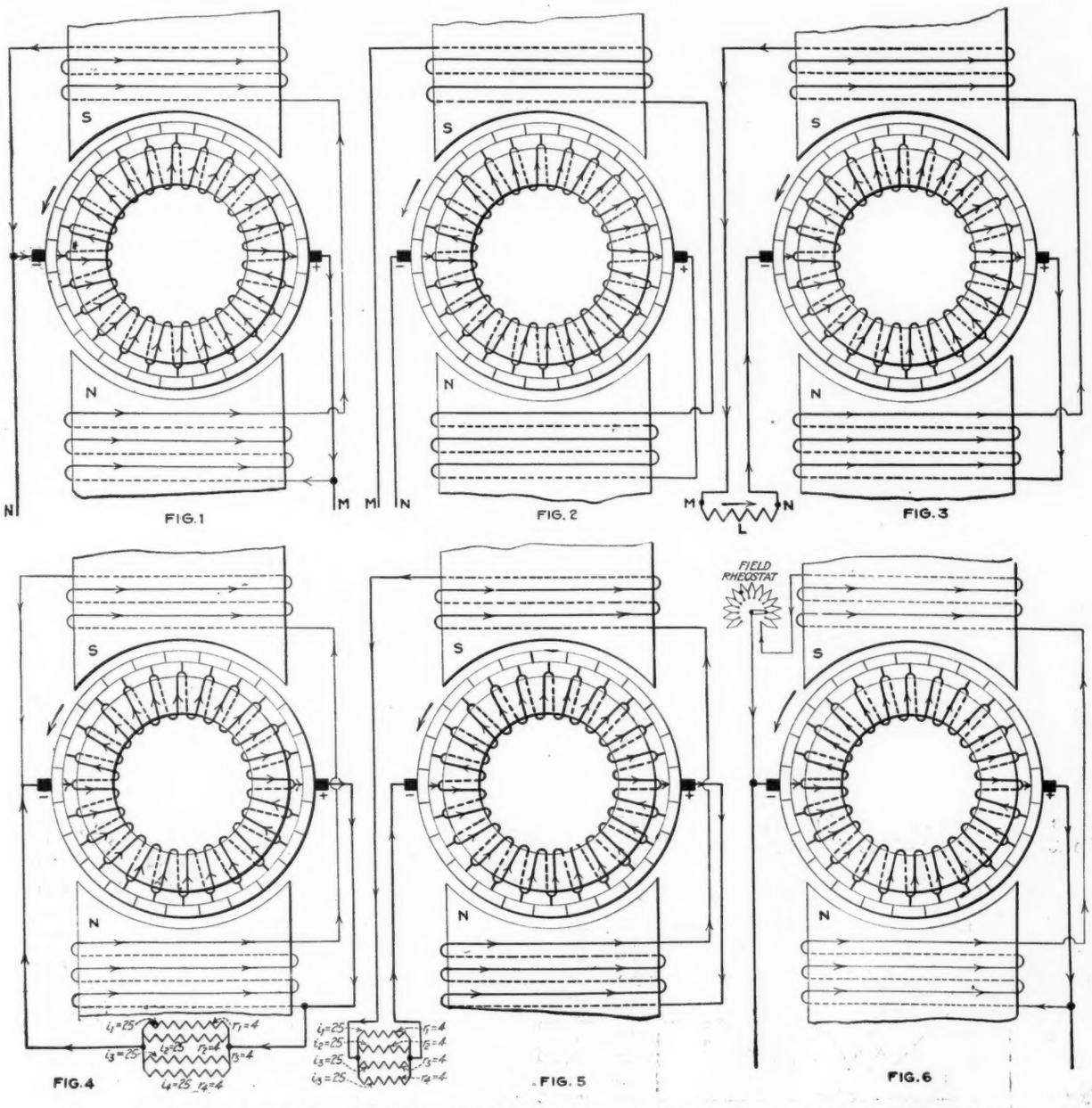
The comparison of the field coils in the foregoing is not absolutely correct, because, in the first case we assume 110 volts at the brushes and in the series machine we have assumed that the total pressure generated is 110 volts. However, the comparison is close enough for all practical purposes and eliminates a lot of calculation.

It is evident that with the series generator if the field strength is to be maintained constant, consequently the voltage at the brushes at a constant value, the load also will have to be maintained at a constant value. This is generally a difficult thing to do, since the load on a generator is usually made up of a number of different devices used for different purposes and of different sizes and types, which are connected to the circuit when wanted and disconnected when not required. The devices also require approximately a constant voltage for their operation. Such a condition cannot be met very successfully by the series generator.

From what we have already seen of the shunt generator, it is evident that the load on the machine does not affect the field circuit. For example, in Fig. 4 is given a shunt generator supplying a load of four resistances, r_1, r_2, r_3 and r_4 each of 4 ohms, in parallel. If we assume that the armature develops 100 volts and neglecting the effect of the armature resistance, the current i flowing in each section of the load is $i = \frac{E}{r} =$

$\frac{100}{4}$ = 25 amperes, or a total of 100 amperes in the four circuits. If one resistance is disconnected from the circuit, the current supplied to the load will be 25 × 3 = 75 amperes, and if only two are connected, the current delivered to the load by the armature is 50 amperes, and for one resistance, 25 amperes. Under any one of the conditions the current flowing in the field coils will remain practically constant since, as shown, this circuit is independent of the load. Consequently, the value of the field current is not affected by the load only as the voltage is caused to vary slightly by the load current and resistance of the armature. This latter factor will be considered in the next lesson.

Now consider what would happen if we varied the load on the series generator, Fig. 5, the way that it was changed on the shunt generator, Fig. 4. In Fig. 5, if we assume the machine to be generating 100 volts and that 100 amperes is flowing in the circuit, then 100 amperes is passing through the field coils. If one section of the load was taken off and if the voltage at the armature terminals remained constant at 100 volts, as was assumed in the shunt machine, 25 amperes would flow through each of the three resistance elements, as in Fig. 4. But with the series machine the pressure will decrease since the current has been decreased in the field coils, consequently the current will decrease in the different elements connected across the armature terminals. From this it is evident that as the load is decreased on the series machine the voltage is decreased and the current through each individual load also decreases; whereas, on the shunt generator the total load may be varied, but the current in the individual loads and the voltage remains practically constant.



FIGS. 1 TO 6. DIAGRAMMATICAL REPRESENTATION OF SHUNT AND SERIES GENERATORS

What we have just seen has practically eliminated the series type of machine from commercial use in preference to the shunt type or modifications of this latter type.

Direct-current generators are generally designed so that, if the shunt-field winding is connected directly across the armature, as shown in Fig. 1, they will at rated speed develop about 120 per cent. normal volts, that is, a 110-volt machine will generate about 125 or 130 volts. The voltage is then adjusted to normal by connecting an adjustable resistance in series with the field circuit, as in Fig. 6. The current through the field coils is adjusted by means of this resistance so as to produce normal volts. Then any slight variation in the voltage, due to changes in load or otherwise, can be taken care of by varying the resistance in the field circuit. The resistance connected in series with the field coils is called a field rheostat.

Fig. 7 is a layout of problem 1 in the last lesson. The joint resistance of the circuit is

$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}}$$

In the problem the joint resistance R is known and r_2, one of the individual resistances, is to be determined. This may be found by transposing the joint-resistance formula around to read

$$r_2 = \frac{1}{\frac{1}{R} - \frac{1}{r_1}} = \frac{1}{\frac{1}{3.75} - \frac{1}{6}} = \frac{1}{\frac{6 - 3.75}{22.5}} = \frac{22.5}{2.25} = 10 \text{ ohms}$$

The correctness of this answer may be checked by substituting the values in the joint-resistance formula; then

$$R = \frac{1}{\frac{1}{6} + \frac{1}{10}} = \frac{1}{\frac{8}{30}} = \frac{30}{8} = 3.75 \text{ ohms}$$

In Fig. 8 is problem 2 of the previous lesson. The resistance of each lamp is 220 ohms and that of the voltmeter 10,956 ohms. The joint resistance of the five lamps is equal to the resistance of one lamp divided by the number of lamps in parallel, or $220 \div 5 = 44$ ohms. Since the group of lamps is in series with the voltmeter, the total resistance of the circuit is $R = 44 + 10{,}956 = 11{,}000$ ohms, and the current $I = \frac{E}{R} = \frac{110}{11{,}000} = 0.01$ ampere. If the voltmeter is properly calibrated, its

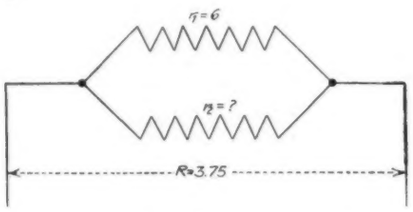


FIG. 7. TWO RESISTANCES CONNECTED IN PARALLEL

reading will be equal to its resistance times the current flowing through it, in this case $10{,}956 \times 0.01 = 109.56$ volts, or a difference of only 0.44 of a volt less than line voltage. This 0.44 volt is expended in the lamps, consequently it is evident that the effect that the lamps would have upon the reading of the instrument could scarcely be detected on the scale. On the other hand, each lamp has 220 ohms resistance and when connected across a 110-volt circuit would take $110 \div 220 = 0.5$ ampere, or $0.5 \times 5 = 2.5$ amperes total current for the group to make them burn at their normal brilliancy; but when connected in series with the voltmeter, only 0.01 ampere flows through the lamps, therefore they

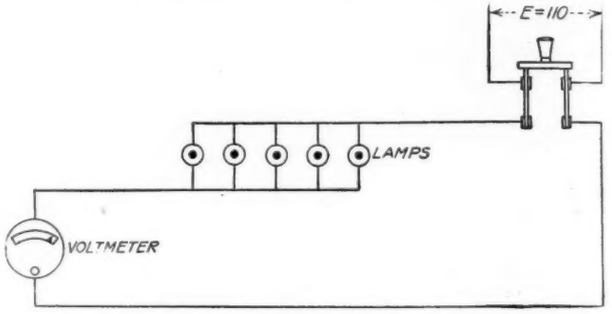


FIG. 8. GROUP OF LAMPS CONNECTED IN SERIES WITH A VOLTMETER

will remain dark, on account of the high resistance of the instrument being in series with them.

1. Find the resistance of 1500 ft. of stranded copper cable made up of 37 wires 90 mils in diameter.

2. A 250-volt 350-kw. two-wire direct-current generator is located 75 ft. from its switchboard; allowing 0.5 per cent. drop, find the size of the conductors required to make the connections between the machine and switchboard.

Ancient Conception of Heat

The early-day theory regarding heat was that it was a material substance, a "subtle imponderable fluid" that was named "caloric." One of the chief constituents of any substance that would burn was supposed to be "phlogiston," and therefore if a substance burned completely or nearly so, it was said to be a pure or nearly pure "phlogistate," and when burned it became "phlogistated."

This theory was proved by melting a given weight of lead and keeping it in a molten state, skimming the surface as fast as a film appeared on it. When all the lead had been so converted into what we now call lead oxide, it was found that its weight was greater than the original lead—therefore phlogiston (heat or fire) had entered the metal, the weight of which was the increase in the weight of the substance. To further prove this theory, it was found that heating this phlogiston-impregnated substance in the presence of or mixed with powdered charcoal reconverted it into metallic lead—the phlogiston was driven out. We now know that it is oxygen from the air that attacks the lead when melted and forms lead oxide, and that when the lead oxide is heated with charcoal (carbon), the charcoal will rob the lead of the oxygen, because of the greater affinity of carbon and oxygen than lead and oxygen, leaving metallic lead again.

Conscription limits the age of the fighting man to thirty years, but there is no age limit for buying Liberty Bonds.

You must buy or pay—buy a Liberty Bond or pay Germany. The $100 Bond is the cornerstone of Liberty.

Coöperation of Public-Service and Isolated Plants

By IRA N. EVANS

A solution of universal application of the old problem of "buying vs. producing current." Coöperation will bring mutual profit, conserve coal and reduce investment for equipment.

THE generation of power in conjunction with heating by exhaust steam has become less profitable in many localities, due to the effort of public-service companies by low rates to control the business at a questionable return to themselves. Making the generation of current seemingly unprofitable for the isolated plant and in some cases taking over the business, still leaves the heating. In numerous instances these heating plants have grown to large proportions. Whether large or small they duplicate to a great extent the power requirements of fuel, labor and unavoidable boiler wastes.

It is a well-known fact that with the most improved methods and equipment only about 15 to 20 per cent. of the heat of the fuel is recovered in current when generated by steam, and 85 per cent. passes up the chimney or into the condenser cooling water. On the other hand, the isolated plant uses 60 to 70 per cent. of the heat of the fuel in the heating system and could easily recover the relatively small percentage convertible into power with practically little or no increase in the total fuel used, provided the functions were properly coördinated.

Mutual Profit in Coöperation

In large industrial plants it is possible to recover all power convertible from the heating fuel by coöperation with the public-service company. There would be mutual profit, conservation of fuel to the community, and the central station would maintain control of the business.

Suppose an industrial plant used 1000 hp. in high-pressure boilers for heating in zero weather and purchased all power used from the public-service company at a flat rate of approximately 1c. per kw.-hr. The heating system would have a condensing capacity of 34,000 lb. of steam per hour in zero weather, and at least 3400 lb. of coal per hour would be burned and paid for in any case. Suppose a turbo-generator of, say, 1000-kw. capacity were installed between the heating system and the boilers and the current metered back continuously night and day into the public-service mains during the period that heating was required. The heating system would be hot water under forced circulation with the exhaust heater of the heating system functioning as a condenser for the turbo-generator.

At about 34 lb. per kw.-hr. and atmospheric exhaust, 900 kw. could be recovered from the fuel burned under the heating boilers, and by varying the vacuum on the heater, the steam rate on the turbine could be lowered as the requirements of the heating system were reduced by the rising outdoor temperature. In this event there would be a constant power-load recovery throughout the heating season, night and day, at a maximum power factor. If 100 kw. were deducted for circulating pumps and plant apparatus, the remaining 800 kw. could be delivered continuously into the public-service mains by utilizing the isolated plant's heating boilers and fuel.

Records of the Weather Bureau show 3782 hours during nights, Sundays and holidays when, in the average plant, heating is required and the power is inoperative. There are 2050 hours during days in the heating season when power is required, making a total of 5832 hours. Consequently, if a turbo-generator of proper size were installed in the heating plant previously mentioned, there would be a net power recovery of 5832 hours $\times$ 800 kw. $=$ 4,665,600 kw.-hr. At 1c. per kw.-hr this would amount to $46,656 for the season. Allowing $100 per kilowatt as a war-time price to cover the installation of superheaters, generating and heating equipment, interest and depreciation aggregating 10 per cent. would amount to $10,000. Extra coal over heating requirements at $5 per ton would cost $7125 and supervision and supplies should not exceed $2500, leaving a balance of $46,656—($10,000+$7125+$2500)=$27,031 to be divided as mutually agreed.

If the isolated plant were supplying its own power independently of the public-service company, it would have to expend from one-half more to double the amount for equipment to guard against breakdown, and during day periods in the heating season would operate only 2050 hours, which would mean a net recovery of 800 $\times$ 2050 $=$ 1,640,000 kw.-hr. This is less than one-half of the previous saving.

Fuel Conservation Effected

If the public-service company generated current on 2 lb. of fuel per kilowatt-hour, the conservation of fuel to the community in the heating season would be 4,665,600 $\times$ 2 $\div$ 2000 $=$ 4665 tons. It is anticipated that the plant would purchase current on the same basis as before, depending on the rebate from current returned to the mains for its profit. It would depend on circumstances and the relative economy of the public-service plant and the turbine under vacuum, whether the machine would be operated during the summer months. No duplicate machinery would be necessary in the isolated plant, as in case of accident the load could be carried for the time being by the central plant, as the unit in the plant would function as part of the public-service company's equipment.

This method of operation would reduce the load on the central station at night and would add to the idle equipment. It will be found, however, that the number of plants available in any one district would be comparatively few and their capacities aggregate a small portion of the night load of the public-service station. They would furnish a source of cheap current during those periods, and as the public-service company has the mains and the only market for the current at these hours, it would have control of the situation.

The period of operation of the turbo-generator, 5832 hours per year, would be greater than that of the large public-service machines operating on a typical industrial-load curve. Where the load on the public-service station is heavier in winter than summer, it would be an advantageous arrangement if the isolated-plant turbine were discontinued during the summer.

It is the writer's belief that this is the most economical and efficient method of handling the isolated-plant problem, and it is applicable to any part of the country for heating plants having over 500 hp. in boilers.

For the assumed case, Table I gives the hours for each 10-deg. period of outside temperature, the steam required for heating, the vacua that would be possible with the water temperatures required and the corresponding steam rates for the turbine. With these data it is easy to figure the total steam and the kilowatt-hours recoverable. The column heads indicate the method. As an interesting comparison Column X gives the electrical energy recoverable from the heating steam by means of a noncondensing reciprocating engine. In moderate weather the noncondensing unit is outdistanced in the ratio of two to one.

The boilers and fuel are purchased and operated in any case by the owner of the heating plant, and no change in this arrangement is contemplated. As will be shown from concrete cases, a saving of fuel will be effected for the owner over the previous method of heating by low-pressure steam sufficient to pay for the changes and modifications of the heating system to successfully operate as a condenser for the turbo-generator.

The ordinary low-pressure steam system is a good condenser of steam, but at pressures at the source all above atmosphere, and this makes it inefficient as an adjunct to power generation. The hot-water system is adapted to use steam at pressures above and below atmosphere. At 3 lb. back pressure it will give an average water temperature of about 200 deg. for zero weather. With a range of about 80 to 120 deg. in moderate weather it will do the heating and still allow a vacuum of 26 in. on the turbine. The arbitrary control of the vacuum regulates the temperature of the heating medium and determines the steam rate on the turbo-generator. When the power and heating loads balance in zero weather it is a fortunate coincidence that the saturated steam used by a turbine decreases with the improving vacuum in almost exact proportion as the heating demand is reduced by the rising temperature. Use of superheated steam upsets the equilibrium somewhat, and it is advisable to use a little additional coal in moderate weather to keep up the power output.

As the turbo-generator uses 100 per cent. more steam under atmospheric pressure than under high vacuum, it is uneconomical to operate in conjunction with a steam-heating system utilizing the exhaust steam for heating. In most cases, therefore, when the question of combining power and heating in the isolated plant arises, a low-pressure vacuum steam system is assumed, which compels the use of reciprocating engines, slow-speed generators and noncondensing conditions the year around, with the result that the space occupied and first cost are excessive and the financial return less favorable. The constant steam rate on the noncondensing reciprocating engine with the widely varying heating requirements causes the recovered power load to range from 100 per cent. in zero weather to less than 50 per cent. in warmer periods, while the variation in the turbine steam rate permits greater recovery. This is shown in Table I.

In a new plant the hot-water system can be installed at no greater cost than a steam system and with no more heating surface if properly designed. The regulation of the vacuum for maximum power will at the same time compel regulation of the heating medium with the outside weather, giving a constant interior temperature. There will be a saving of 25 to 30 per cent. in the heating steam over the constant-temperature low-pressure steam-heating system, or more than sufficient to allow for additional fuel to raise the steam pressure for power purposes. The power operation will give an opportunity to utilize for feed-water purposes all steam from auxiliary pumps of the heating plant, which is generally wasted due to the high temperature of the return condensation.

In ordinary low-pressure steam plants using steam at 5 lb. pressure, the boilers are operated at from 100 to 140 lb. pressure and steam is supplied through a reducing valve. The total heat per pound at 140 lb. pressure is 1194 B.t.u., and the temperature 361 deg. F. If the steam is reduced to 5 lb. pressure, the temperature is actually 308 deg., showing that at this pressure the steam is superheated 80 deg. The corresponding pressure for the temperature is nearly 61 lb. gage. As the loss of heat from pipe surfaces is proportional to the temperatures and not the pressures, the heating system

TABLE I. POWER RECOVERABLE FROM HEATING FUEL IN INDUSTRIAL PLANT WITH 1,000 BOILER HORSEPOWER FOR HEATING IN ZERO WEATHER

I Outside Temp. Periods Deg. F	II Hours Nights, Holidays	III Hours Work Days	IV Total Hours Each Period	V Steam per Hour Lb.	VI Vac., In. Hg.	VII Av. Water Temp., Deg. F.	VIII Turbine Rate, Lb. per Kw.-Hr.	IX Recov. Power Heating Steam Kw.	X Recov. Power Non-Cond. Engine Kw.	XI Turbine Rate Const. Load 900 Kw. Lb.	XII Gross Load Carried Kw.	XIII Net Load Carried Kw.	XIV Evap. Factor 175 Lb. 100 Deg. F. & A. 212 Deg.	XV Steam per Hour Power Heating F. & A. 212 Deg.	XVI Total Steam Power and Heating F. & A. 212 Deg.	XVII Total Steam for Heating
0–10	211	97	308	30,000	3	194	31.4	956	857	31.4	956	856	1.134	34,041	10,484,628	9,240,00
10–20	566	251	817	26,600	9	182	28.4	937	760	28.4	937	837	1.134	30,176	24,653,792	21,732,200
20–30	719	423	1,142	23,300	14	170	26.2	889	665	26.2	900	800	1.134	26,740	30,537,080	26,608,600
30–40	766	354	1,120	19,800	20	154	22–8	870	565	22.6	900	800	1.134	23,065	25,832,800	22,176,000
40–50	622	290	912	16,200	24	135	20.2	802	463	19.8	900	800	1.134	20,208	18,429,696	14,774,400
50–60	475	271	746	14,100	26	115	18.8	750	403	18.0	900	800	1.134	18,371	13,704,766	10,518,600
60–70	423	364	787	12,000	27	110	18.8	638	343	17.0	900	800	1.134	17,350	13,654,450	9,444,000
	3,782	2,050	5,832												137,297,212	114,493,800
														Tons of Coal (Evap. 8 Lb.)	8,581	7,156
														Cost of Power 1,425 Tons	.....	.....

Note—Column IX = Col. V ÷ Col. VIII; Col. X = Col. V ÷ 35; Col. XIII = Col. XII − 100; Col. XV = Col. XII × Col. XI × Col. XIV; Col. XVI = Col. XV × Col. IV; Col. XVII = Col. V × Col. IV.

is actually operating at a temperature corresponding to 61 lb. pressure instead of 5 lb. and will use more steam. This accounts for the frequent statement of many engineers that they find little difference in fuel if they operate the engines and heat with exhaust steam or heat by live steam at reduced pressures, the power costing nothing. No one would wonder at an increase in fuel if told the system was operated at 60 lb. instead of 5 lb. pressure, and this is virtually what happens. The heat all goes into the building, but is generally lost in mains and nonessential places.

This is obviated with the hot-water system owing to the use of the heaters: one for live steam with gravity return to the boilers for use when the engines are inoperative, and an exhaust heater that utilizes the exhaust steam at atmospheric pressure and below. The water is passed through both heaters in series, and all steam at whatever pressure is converted to water temperatures always the same for the same outside temperature. The steam is piped a comparatively short distance.

A Concrete Case in Point

In substantiation of the previous statements the writer has a concrete case and approximate conditions in two other plants to offer. The plant first mentioned is heated by live steam reduced to 5 lb. pressure and the others already have forced hot-water heating systems and purchase current. The steam-heated plant operates 1600 hp. in Stirling boilers at 150 lb. pressure. The second plant is shut down in summer, but during the heating season operates 800 hp. in boilers. The third plant will have 2000 hp. in boilers, a portion to be operated throughout the year. Table I will serve to show the possibilities in the first plant if the steam system were changed to hot-water heating and the plant operated as previously suggested. Inasmuch as there are turbine feed pumps and engines to drive the forced-draft fans, the additional fuel for the higher pressure and for heating the feed water will be practically nothing, although the factor of evaporation is taken from the temperature of 212 deg. in each case to 175 lb. and 100 deg. superheat. Table II summarizes the possible saving in each of the three plants.

In the three plants there is recovered from heating steam 11,078,600 kw.-hr. At 2 lb. of coal per kilowatt-hour in the central station, this represents 11,078 tons of coal per season. In the first plant there is a net saving of 2000 tons of coal for power and heating combined over heating alone, and in the other two plants an addition of 1250 tons is required for power over heating. The net saving to the community is 11,828 tons of coal, which at $5 per ton amounts to $59,140. At 0.95c. per kw.-hr. the recovered current is valued at $105,247, which is nearly 60 per cent. of the total expenditure.

In plant No. 1 the actual fuel purchased for heating in 1915-16 was 9000 tons, or 2000 tons more than required to heat by hot water and recover 4,665,600 kw.-hr. The difference in fuel pays a large return on the investment required for changing the heating system. In this plant two large air compressors are operated the year around and only part of the exhaust is used for heating on a near-by building. High-pressure steam for heating is reduced from 140 to 5 lb. through a reducing valve. In summer 20 tons per 24 hours is used to operate the plant Sundays and holidays when no work is accomplished. The turbine feed pump and forced-draft fan engine practically exhaust to atmosphere, as all condensation is returned to the boiler room at a comparatively high temperature. If vacuum were carried on a turbine unit for power, there would be ample exhaust from auxiliaries to heat the feed water to 200 deg. at least.

Plant No. 2 has a hot-water plant and would require only a 350-kw. machine and the heaters changed to carry a vacuum on the turbine. The coal is not weighed and the boilers are operated below rating under less than 100 lb. steam pressure. Plant No. 3 has a hot-water heating system, 2000-hp. in boilers and a large noncondensing air-compressor plant operated throughout the year. Current is purchased for power and lighting and there is probably a total consumption of four to five million kilowatt-hours per year.

TABLE II. TYPICAL ILLUSTRATION WHERE LARGE SAVINGS ARE POSSIBLE

Plant No. 1		
Steam Heating, 1600 Hp. in Boilers		
Heating fuel as per record, 1915-16, 9,000 tons at $5		$45,000
Power purchased, 3,336,225 kw.-hr. at 0.95c		31,694
Operating cost		$76,694
Cost changing heating to hot water	$60,000	
Cost generating equipment, 1,000 kw	75,000	
Int. and dep., at 10 per cent. on	$135,000	$13,500
Power and heating fuel, 7,000 tons at $5		35,000
Attendance and supplies for 6 months		3,000
Gross cost		$51,500
Kw.-hr. recovered 800 × 5,832 = 4,665,600		
Surplus kw.-hr. 4,665,600 — 3,336,225 = 1,329,375 at 0.95c		$12,629
Net operating cost		$38,871
Net saving ($76,694 — $38,871)		**$37,823**
Plant No 2		
Hot-Water Heating, 800 Hp. in Boilers		
Int. and dep. on gen. equipment and heaters (10 per cent. on $21,000)		$2,100
Extra fuel for power over heating, 350 tons at $5		1,750
Attendance and supplies, 6 months		2,000
		$5,850
Kw.-hr. recovered, 250 × 5,830 = 1,457,500 at 0.95c		$13,846
Net saving ($13,846 — $5,850)		**$7,996**
Plant No. 3		
Hot-Water Heating, 2,000 Hp. in Boilers		
Int. and dep. on gen. equipment (10 per cent. on $75,000)		$7,500
Extra fuel for power over heating, 1,100 tons at $5		5,500
Attendance and supplies, 6 months		3,000
		$16,000
Kw.-hr. recovered 850 × 5,830 = 4,955,500 at 0.95c		$47,077
Net saving ($47,077 — $16,000)		**$31,077**

In plants Nos. 1 and 3 it would pay the owners to generate their own power independently, but the installation would have to be at least 1500 kw. instead of 1000 kw., with a corresponding expenditure and with little greater saving than would be attained by operating the heating boilers for power in conjunction with the public-service company.

The foregoing outline, if adopted in some form, will make the public-service plant stronger and more profitable and solve the question of unprofitable rates to large consumers who are shirking the responsibility of generating their own power and are actually wasting the community's fuel. The system could be adapted to office buildings having over 500 hp. in boilers by operating a turbine during the heating season to recover the electrical energy from the heating fuel, purchasing all current required above this amount in winter and buying all current during the summer months. This would also help solve the district-heating tangle, due to the high cost of fuel, but with this difficulty—the changing from steam to hot-water heating.

Exhaust Pits for Low-Compression Oil Engines

By L. H. MORRISON

Forms of exhaust pits are described, together with means for preventing accumulations of discharged oil and avoiding damage by explosions.

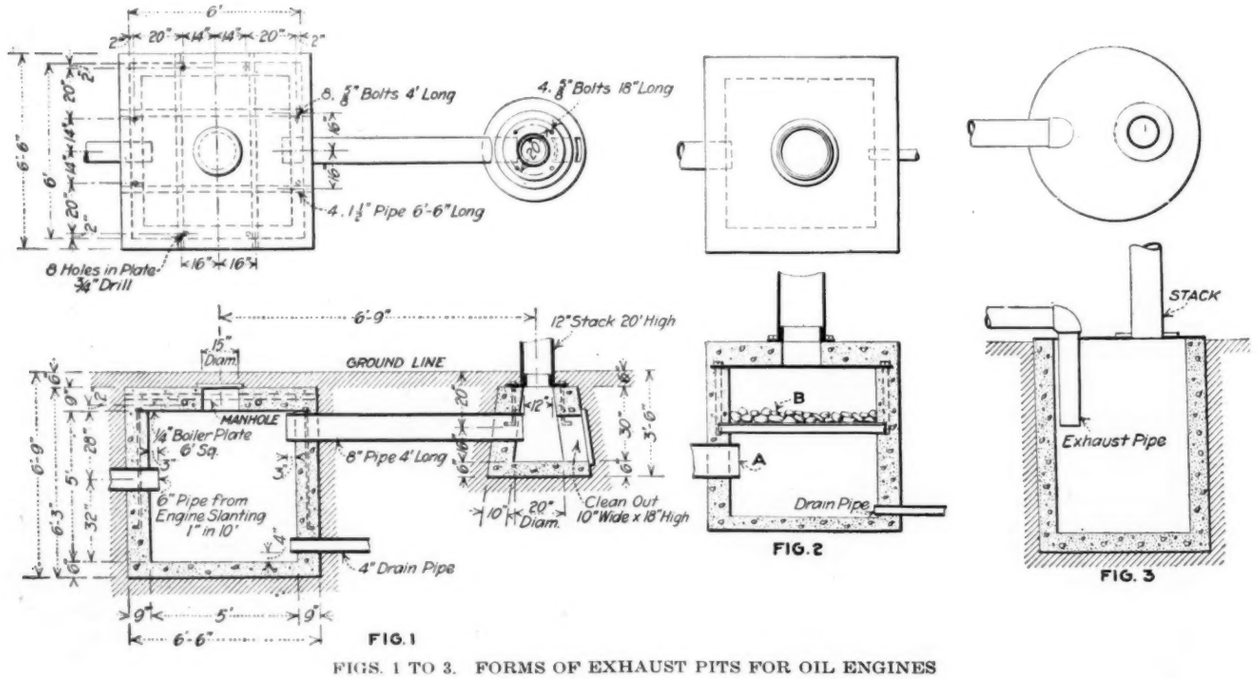
EVERY low-compression oil engine, no matter where it is installed, should be provided with an exhaust pit. It is the practice of some manufacturers to furnish a cast-iron exhaust pot, which is located close to the engine. While this assists in dampening the noise of the exhaust, it does not, by any means, take the place of a pit.

Low-compression engines, regardless of make, display a tendency to allow part of the fuel charge to blow out through the exhaust ports while it is in a liquid condition. This is especially noticeable when an oil having a heavy asphaltum base is used, because the cylinder temperature is not high enough to vaporize the heavier portion of the oil. The same objection frequently is raised against heavy fuel when the engine is operating on low loads. On low loads the temperature of the bulb or hot ignition device falls so low that it is unable to vaporize completely any of the fuel oils ordinarily used. As a consequence, some oil must enter the exhaust pipe. The same condition is often encountered when the governor and the injection nozzle fail to cut off the oil supply at the proper point.

If the discharged oil is trapped in an exhaust pot located close to the engine, it will accumulate until it is set afire. The exhaust is always at a high temperature, and frequently a flame blows through the exhaust ports and ignites this residue. Many fires, some of them serious, have resulted from the use of the exhaust pot or muffler.

To overcome the objection to the pot, a concrete exhaust pit should be constructed outside the building. It is a good plan to place the pit at least five feet from the building wall. Means should be provided for draining away the residue that accumulates in the pit. If the contour of the land permits, the drain should have an open end. If not, it should be run to a smaller pit and a bucket should be placed in this pit below the drain. In this way the residue will collect in the bucket and can be removed.

Fig. 1 shows a form of exhaust pit much used. It is provided with an extra exhaust-stack pit leading from the pit proper. While this is of assistance in deadening the noise, it is a refinement not actually required. Note should be taken of the reinforcement of the concrete. This will resist the ordinary strains to which the walls are subjected. It is necessary to use a manhole, both for access to the pit and for safety in case a violent explosion occurs.



FIGS. 1 TO 3. FORMS OF EXHAUST PITS FOR OIL ENGINES

Another good form of pit is shown in Fig. 2. Here the exhaust pipe *A* enters below the layer of rock *B*, which is supported by old rails or iron bars and serves to deaden the sound of the explosions. Such a pit is well-nigh noiseless. It should be provided with a manhole in the side, below the layer of rock. This manhole can be fitted with a thin cover held in place by two small studs, so that, if a heavy explosion should occur, the cover will blow off and prevent damage to the pit.

Frequently a cylindrical exhaust pit like that shown in Fig. 3 is used. This, however, is not of good design, as it does not even deaden the noise of the exhaust. Furthermore, as it has no drain, the residue cannot be removed readily.

The pit should be so located that its top will be a few inches below the ground level. The exhaust pipe should be a size larger than the flange on the engine, in order to provide a free exhaust, and the pipe from the engine should slope down toward the pit, in order to drain well.

The exhaust stack from the pit should be considerably larger than the exhaust piping; for instance, if an exhaust pipe 8 in. in diameter is used, the stack should be at least 12 in. in diameter. Owing to initial cost it is customary to use a sheet-steel stack of from No. 8 to No. 16 gage. Corrosion in the stack is generally severe, and as a consequence the heavy gage is cheapest in the long run.

Large Single-Phase Transformers

Four of the largest single-phase transformers ever built were recently shipped by the Westinghouse Electric and Manufacturing Co. from East Pittsburgh, Penn., to a Southern power company. These units, one of which is shown in Fig. 1, are rated at 14,000 kv.-a. 60 cycles, and since they have a 25 per cent. overload rating, they have practically a 17,500-kv.-a. maximum capacity.

They will form a 42,000-kv.-a. bank, which, together with a spare unit, will make the preliminary installation to step up the voltage of the waterwheel-driven generators from 13,200 to 150,000, the highest transmission voltage used today. Power will be transmitted about 25 miles to an industrial plant, where it will be stepped down by means of a number of 7000-kv.-a. single-phase transformers of similar characteristics, ten of which have recently been built by the Westinghouse company.

Owing to the large size of the 14,000-kv.-a. units and the great amount of generating capacity that will ultimately be concentrated behind them and their need to be able to withstand the effects of momentary short-circuits, the shell type with the special end frames and bracing arrangement shown in Fig. 2 was selected. Structural steel for these parts was used throughout, because the strength of the various members can be depended upon to a much greater degree of certainty than with castings. The top and bottom ends of the coils are held against distortion by two heavy steel plates, each reinforced by four lengths of angle iron riveted to them and held together by four heavy tie-rods.

The tanks are made of heavy boiler plate, all seams being oxyacetylene-welded. A structural-steel base with wheels supports the tank. The high-tension terminals are of the condenser type protected by means of a number of porcelain rain shields to adapt them to outdoor service.

Some idea of the size of these units may be gained from the fact that their height measures 23 ft. 6 in. from the top of the high-tension terminals to the base, and each unit weighs complete with oil and fittings approximately 110,000 pounds.

White Power in Italy

According to P. Lanino, an Italian authority who has recently published four volumes on "La Nuova Italia Industriale" (The New Industrial Italy), Italians in general have cause to be optimistic on the question of the utilization of water power. In 20 years, he points out, about 1,000,000 hp. of water has been harnessed, and it is estimated that from 2,000,000 to 6,000,000 hp. is readily available, while the potential horsepower ranges as high as 20,000,000. Within ten years 300 kilometers (186.5 miles) of railroad have been electrified, and plans have been prepared calling for the electrification of 2000 kilometers (1243 miles) more—one-seventh of the total mileage in Italy.

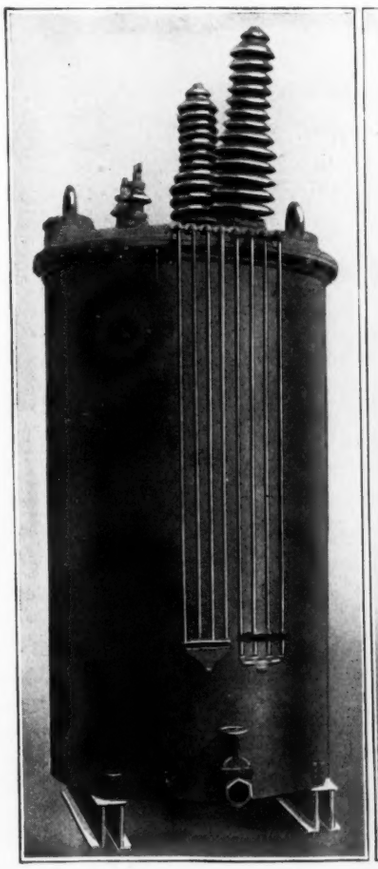
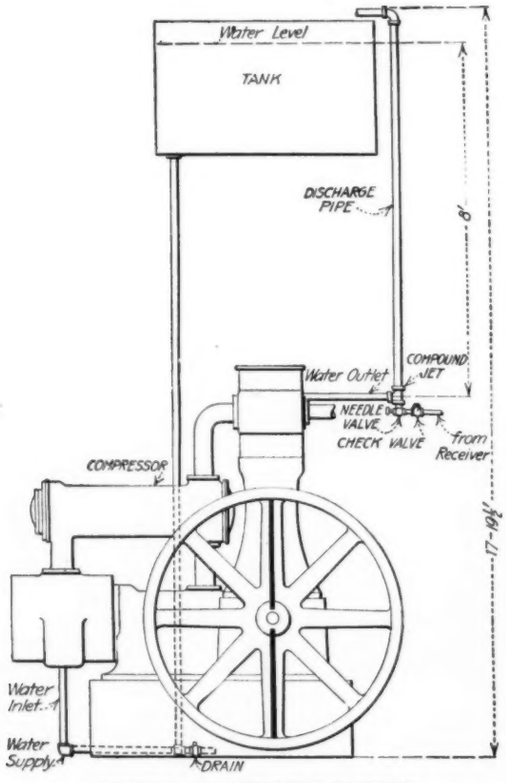


FIG. 1. TRANSFORMER COMPLETE

FIG. 2. CORE AND COILS OF TRANSFORMER ASSEMBLED

Air Lift for Compressor-Jacket Water

The accompanying illustration shows how the air-lift system of pumping can be utilized to form a simple and effective method of supplying cooling water to air-compressor cylinder jackets. A small tank is placed



PIPING OF AIR-LIFT SYSTEM

about eight feet above the compressor, which gives sufficient height to permit the water to flow by gravity through the jackets. Instead of using a pump for this purpose or for elevating the water to the gravity tank again, a needle valve or, still better, an air-lift mixing tube controlled by means of a pin valve, is placed at the base of the riser, just outside of the water-jacket discharge. This valve is connected by a small pipe with the air receiver, and a small amount of air is thus forced into the riser pipe, acting to carry the water from the cylinder jacket back to the elevated tank.

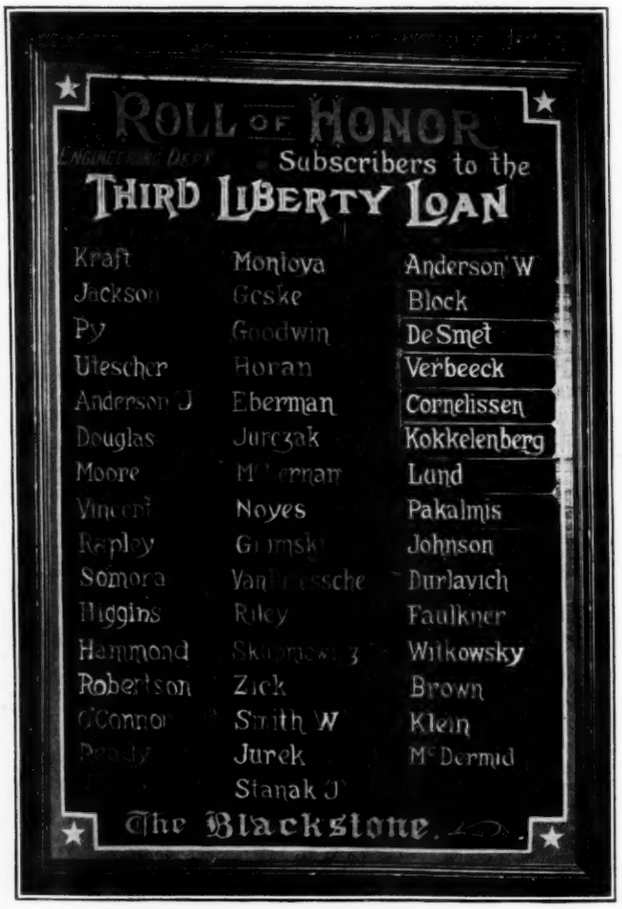
The amount of water required depends, of course, on the size of the compressor. A 10 x 10-in. single-stage machine, having a capacity of 213 cu.ft. per min., would require about 5 gal. per min., and for this a 1-in. pipe would be sufficient.

This plan of automatic cooling water circulation, says *Mine* and *Quarry*, was worked out by George H. Richey, one of the engineers of the Sullivan Machinery Co. at Boston, who has placed it at several installations in New England, as a substitute for a small centrifugal pump driven by an electric motor. Excellent results are obtained, and the heat in the water is reduced to a considerable extent by the expansion of air in the riser or eduction pipe. The sketch shows the system as installed for a two-stage angle-compound compressor. It is, of course, even simpler with a single-stage machine. In the installations referred to, no trouble has arisen, and the system has kept the compressors properly cooled.

Blackstone's Roll of Honor

W. A. Eberman, chief engineer of the Blackstone Hotel, Chicago, has been a patriotic worker in the campaigns for the three Liberty Loans. To further subscriptions among employees of the engineering department of the hotel, he has instituted a Roll of Honor. As soon as a man signs up for a bond his name is entered in gilt letters on the board shown in the accompanying illustration. Its dimensions are about 4 x 6 ft., and it is mounted in the engine room in plain sight of the force. There is a border of red, white and blue; the frame is gilt and the roll is golden literally and in spirit as well, for 48 of the 50 men in the department have subscribed to the Third Loan and the other two have agreed to invest a definite sum in Thrift Stamps. The efficiency is 100 per cent.

In looking over the names there is a cosmopolitan variety of nationalities represented: German, Bohemian,



Austrian, Belgian, Swedish, Russian, English, Irish and Scotch. All have shown their patriotism. Not one has failed to subscribe. It is a gratifying example of what can be done and is a leading suggestion to other large plants.

At times nails and pegs are found extending from walls at face level to hold tools and clothing. Such projections make dangerous hazards when not in use, and they should be removed. Clothing should be hung in lockers, and firing tools should preferably be kept in racks.

Editorials

The Ultimate B.t.u.

THE central-station folks have been raising a considerable hullabaloo of late—to be particular, since the Fuel Administration has begun to ferret out the places where coal is going to waste—about the terrible inefficiency of the isolated plant in the generation of power. In the same breath they have been making considerable fuss over the wonderful efficiency of the central station as a power producer.

The point at issue between the two types of plants, so far as the Fuel Administration is concerned, is simply one of coal conservation, which may be expressed in another way as making a pound of fuel go just as far as possible in producing useful effects. Under this broader interpretation of the problem, the isolated plant has a strong case against its powerful opponent.

Observe what happens to a pound of coal in the central station. It goes majestically to the furnace on a chain-grate chariot, flares up in one swift burst of incandescence, and gives all its latent energy to a swirl of gases that sweep the boiler, caress the tubes of the superheater and are whisked away through the economizer to the chimney, while from the boiler flows that aristocrat of heat mediums—superheated steam.

The steam—thermal offspring of that pound of black, prosaic coal—rushes lightly through the main, enters the turbine, flirts daintily with the flying blades, and leaves, with its energy only slightly diminished, to give up all its remaining heat to the condensing water; and that condensing water, carrying with it about eight-tenths of the heat liberated from the stodgy pound of coal, goes merrily seaward to warm the fishes, who don't need warming and are totally ungrateful for the favor so graciously bestowed.

By contrast, see what happens in the isolated plant. The pound of coal is heaved unceremoniously through the fire-door by a member of the strong-arm squad, breathes its last on an old-fashioned herringbone grate, and passes its heat into a boiler that produces a slug of plain, ordinary wet saturated steam—the common garden variety discovered by Watt some decades ago.

That slug of steam eventually finds its way into the cylinder of an old-fashioned reciprocating engine, where it churns to and fro, spends a small fraction of its energy in generating power, and escapes clumsily and soddenly into the exhaust pipe, still holding in its keeping about nine-tenths of the heat it received from the pound of coal.

But no condenser yawns invitingly to receive it. That little trip through the engine was mere play. The real work is about to begin. A houseful of radiators waits to claim some of that exhaust steam for heating; some of it goes to a hotel kitchen to aid in cooking; some of it goes to a laundry, where it helps to heat water and dry clothes; a part of it enters the generator of an absorption plant and furnishes refrigeration for cooling and ice-making; and after all these varied interests are served, if there is anything left of that slug of wet steam—which there usually isn't—it escapes through an exhaust stack, a mere ghostly wraith, scarcely visible to the naked eye. Meanwhile, the steam that has done this work is a collection of streams of hot water that are collected, drained into a trap, and sent back to the boiler, carrying with them the last B.t.u. that can be reclaimed.

When it comes to utilizing the last heat unit in a pound of coal, the isolated plant for combined lighting and heating need not take off its chimney cap to any central station.

Launch a Blow in Defense of Liberty

ALL newspaper readers are familiar with the reports from Washington which interpret the weather map. We read, for example, that an area of high pressure is static over the Middle Atlantic States, or we learn that a "disturbance," originating in the far Southwest and centering for the moment over northern Texas, is moving rapidly northeastward and within forty-eight or sixty hours should bring us a violent and sustained storm.

From the German point of view our Liberty Loan campaign is just such a "disturbance," collecting the elements of its future fury thousands of miles away. Through the mysterious channels by which their arrogant leaders are kept informed of the activities of this land, the Germans learn of the gathering storm, and they watch its development with an anxious intensity second only to their keenness for word of the tide of battle in France. They know that as fast as these Liberty Bonds are converted into guns and munitions and put into the hands of American soldiers, the "disturbance" will move upon them with the inexorable force of a cyclone traversing a continent. And they know also that when it arrives it will beat against them, uprooting and sweeping away their defenses, with just that degree of violence which is imparted to it in the beginning by the will of its originators.

That is to say, it is the initial impulse which places limits to the force of any drive, and in the case of such an offensive as that just described the initial impulse comes from the patriotic hearts and pocketbooks of one hundred million Americans. If they respond to the challenge, each to the limit of his ability, eagerly, passionately, completely, the Germans will know that they are in for a cyclone such as only America can breed.

There is not an American among us who can afford to stand by and watch the launching of this tremendous blow for liberty without contributing to it his full share of patriotic frenzy expressed in cold cash. The money will come back increased with a bountiful interest, but that is not the main point for the investor; this lies in the opportunity it will give him to get in his particular jab against the barbaric enemy which, with all

the vicious ferocity of desperation, is seeking to trample under foot our boys "over there," our Allies' boys, our Allies' fair lands and homes and liberties and, beyond them, our own. There isn't a man with a single minim of American blood in his veins today who wouldn't give his all to check the freshet of Boches on the western front. Here is his opportunity. Let him join the storm that sooner or later will set that appalling flood rushing the other way. Specifically, let him invest as much of his money in bonds of the Third Liberty Loan as he can spare from the necessary daily expenses of his existence.

Combustion and Furnace Design

WHAT is perhaps the most valuable bulletin on the subject of combustion and its influence upon the design of furnaces has been issued recently by the Bureau of Mines. A full review, together with remarks on this bulletin, appears elsewhere in this issue. Experience has taught that high boiler settings with great furnace volume have greatly improved combustion, but it is safe to say that most of us have not known fully the reasons why. We have known that stoker-fired furnaces of large volume have given far better mixtures of the air for combustion and the combustible gases than is obtained in the ordinary hand-fired setting. The bulletin corroborates experience which tends to show that, although engineers have carried the ordinary water-tube boiler settings to a height of twelve feet from the bottom of the front tube headers to the floor line, even this height, great as it is compared with practice of a few years ago, is not sufficient with ordinary settings to insure the most desirable conditions for commercially perfect combustion. It is interesting to note that the investigations of the authors of the bulletin show that there is a definite relation for each coal between the excess of air supply and CO_2.

The percentage of excess air that gives the best results in any steam-generating apparatus varies with the size of the furnace and the kind of fuel. In two furnaces burning the same fuel but having different sizes of combustion space, the one with the smaller space may receive more excess air for the best results than the one with the larger combustion space. Also, of two furnaces exactly alike in size but burning different coals, the one burning coal lower in volatile matter and oxygen gives better results with lower excess of air than is necessary for the best results in a furnace burning the coal higher in volatile matter and oxygen. This explains why in one plant the highest efficiency may be obtained with fourteen per cent. of CO_2 in the gases, and in another plant with only ten per cent. of CO_2. In other words, the investigation brings us much nearer to a general understanding of the reasons why the statement which claims that efficiency is always highest with the higher CO_2 may be questioned when applied to the usual boiler setting. It is likely true that if one could design a furnace to give a thorough mixture of the air for combustion and the combustible gases, maximum furnace efficiency would occur when the CO_2 was at a maximum; but in the usual boiler furnace we must depend in great measure upon an excess of air to obtain the best mixture of air and combustible gases under the local conditions. We direct particular attention to the pages of the bulletin which deal with the subject of soot formation. The authors point out that soot is formed at the surface of the fuel bed by heating the hydrocarbons distilled off from the volatile in the coal in the absence of air; it is not formed by the hydrocarbon gases striking the cooler surfaces of the boiler. It is pointed out that only a very small trace of the hydrocarbon gases ever reaches the surface of the boiler. In other words, the cooling surfaces do not cause or promote the formation of soot, but they merely act as collectors of it.

Pages 134 to 137, the last in the bulletin, are especially interesting. In these pages the authors point out that the volatile matter in soft coal may be distilled off and converted into liquid fuel for motor purposes, in which form it has a value from twenty to thirty times as great as that in the form of coal. As the supply of bituminous coal is enormous, the uses of the oil are practically unlimited and the margin of profit in the conversion is large. It would seem that the development of highly productive methods would be rapid. By itself the coke residue from such reduction plants would have considerable commercial value, and if its price were made equivalent to coal, it would doubtless find a wide market for house heating and steaming purposes. The authors say that vague reports from Europe indicate that after the war the world will be informed of some extraordinary developments in the utilization of bituminous coals in certain countries, and that these developments will be of pressing importance to American manufacturers. One notices that two or three different companies have been formed recently for the purpose of distilling the highly volatile matter out of bituminous coal, using the residue for steaming purposes, while the distillates are to be used for chemical and motor fuel purposes. *Power* has, from time to time, pointed out that some day it would be the chemist who would reveal to the public the wasteful manner in which the engineer uses coal by giving the people a truer conception of the intrinsic value of bituminous coal. This seems to be the beginning.

There is no doubt that the Fuel Administration's zone system for the distribution of bituminous coal will effect considerable saving in transportation and will, if entered into in the right spirit by the mine owners, dealers and the people, help to avoid such deplorable shortages as occurred last winter. That the country as a whole may be benefited some consumers must be inconvenienced. Many plants in Illinois, for example, long accustomed to the West Virginia low-ash, low-volatile coal, must now use the high-ash, high-volatile coals of Illinois. Consumers in Iowa, Kansas, Missouri and Nebraska, particularly, can no longer get the West Virginia coals, but must use the coals produced in their own districts. The whole Middle West and Northwest is thus affected. For these people many new combustion problems will arise. *Power* hopes soon to begin the publication of articles written especially to help these consumers solve such problems.

The engineering world is still waiting for the report of the committee of scientists who were to determine whether the Garabed should receive a laurel crown or merely a casket bouquet.

Correspondence

Handy Extension Lamp Cord

The illustration shows a drop-light arrangement that I have found very convenient for use in places where a light is needed for inspecting the interior of ice tanks and the like, and that at other times is available for general illumination. It consists of a spring taken from a shade roller fastened to a drop-light cord, which should be of suitable length so that the light will be lifted out of the way when not in use within the tank.

SPRING SUPPORT OR HOLDER FOR DROP LIGHT

St. Louis, Mo. ARNOLD JAMES.

Fatal Explosion of Home-Made Boiler

In the local morning paper several days ago I saw in large headlines, "Boiler Explodes, Frozen, Kills One Man." Anxious to learn the details of the case, I went, in company with another inspector, to the scene of the accident. How the writer of the article knew that the boiler was frozen still puzzles me, for we could not obtain enough information from our investigation to arrive at such a conclusion, as not a particle of the boiler proper could be found. The fire-door frame was found about a block away, and there was no one about the plant at the time of the accident except one young man who, unfortunately, was instantly killed.

A boy about 16 told us he had seen the boiler installed, and upon questioning him regarding its design, he said that they had taken an ordinary kitchen hot-water tank, suspended it with iron bars, built a furnace of rock under it and used it to produce steam to sterilize milk cans and for other cleaning about the dairy. As to whether there was a steam gage, water column or safety valve, no one knew, but I doubt it. Judging from the damage done, there was a tremendous pressure on the boiler at the time of the explosion. The building was completely wrecked, and rock from the setting was scattered over a radius of five hundred yards; and one of the fireman's feet was found two hundred yards from the plant and in almost the opposite direction from that in which the body was hurled.

This boiler was within the city limits and should have been inspected by the city inspector. It is stated on good authority that it had been in service for several years, but the city had no record whatever of it or it probably would have been eliminated. It appears to me that the life of this promising, able-bodied young man was lost because the people of the State of Washington have not seen to it that laws under which steam boilers must be properly designed and operated are enacted and enforced.

By far too many of us say nothing until after such an accident and then jump at the conclusion that the boiler was frozen or that the fireman was to blame for various reasons.

I have inspected boilers in eight states, some of them having no boiler laws, and the probability, in my opinion, is that more lives will be lost if all states do not promptly wake up to the fact that there should be standard boiler designs, compulsory inspection and licensing of engineers and firemen. R. S. HART.

Spokane, Wash.

Alternating Current Cannot Cause Corrosion

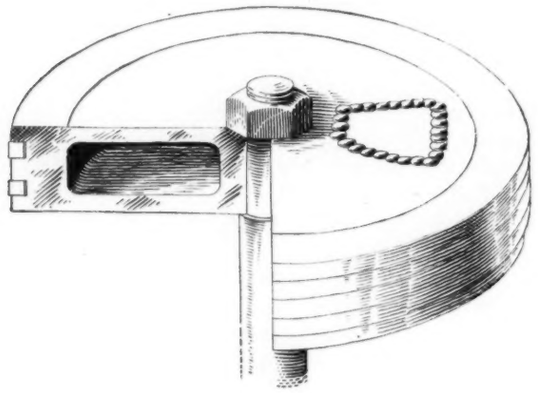
The only effect of eddy currents that would cause the water-pipe joint to corrode as mentioned in the article "Lighting Circuit Caused Water-Pipe Joint to Corrode," in *Power*, Feb. 5, would be of a thermal nature. Such effects require that a large current be induced in the pipe, which in turn requires that the inducing circuit have considerable ampere turns and high frequency. This is true since the induced currents are proportional to the induced potential and the pipe resistance, the former being dependent on the flux changes.

The small amount of energy involved in a lighting circuit would at once eliminate it as a cause of corrosion. It is highly probable that stray direct current from a railway is entering the building through the water line and that the trouble is due to a high resistance joint at the point of corrosion. If electrolytic action is due to an electric current, then it must be direct current since an alternating current will not cause such action. (See Bureau of Standards "Technologic Paper" No. 72.) H. E. WEIGHTMAN.

Chicago, Ill.

Broken Cast Piston Repaired

The piston of a large vertical engine had a hole "punched" in it when the "keeper" key, holding the nut in place on the rod broke and got over into the clearance space. The engine was urgently needed and had to be repaired as quickly as possible. Welding would necessitate heating the entire piston to some extent and might distort it. It was therefore decided to "sew" the piece back in. We drilled and tapped



HOW A BROKEN PISTON WAS REPAIRED

holes along the crack and put in ½-in. cap bolts and sawed the heads off. One bolt overlapped the other so that they could not unscrew and work out. The job was completed in a short time and was entirely satisfactory. GEORGE H. DIMAN.

Lawrence, Mass.

Static Electricity from Gasoline

In the issue of Jan. 22, page 130, D. R. Gibbs states that gasoline flowing from a spigot into an ungrounded can will produce sufficient static electricity to ignite itself. This will also occur if the liquid used under the same conditions is benzine or naphtha.

In the manufacture of paints and the grinding of pigments, where the solvent or vehicle is naphtha, gasoline or turpentine, the ignition of the liquid is liable to occur, especially with high-speed apparatus, and I have known fires to be caused by an operator touching the metal tank sides with a steel scraping knife. Grounding the apparatus is not always a preventive for if the tank be of considerable size its entire area may become charged and act as a storage of low potential, and there may not be sufficient difference of potential between it and the earth to cause discharge. Grounding is, as a rule, satisfactory in conducting to earth a static discharge where a considerable difference of potential exists; as, for example, in a fast-traveling belt.

In theory the earth is regarded as at zero potential, but in practice it is claimed that with a difference of less than 4000 volts potential grounding static discharges is ineffective, and other means are resorted to, as follows: Humidification will so dissipate the static charges that they will not build up sufficiently to produce sparks hot enough to raise even inflammable gases to the ignition point. Humidification may be produced by a steam jet, or in the absence of steam, water sprinkled around will produce enough moisture to secure relief. If humidification is objectionable, and it is in many of the processes of manufacture, circulating currents of air, preferably hot, will be found advantageous.

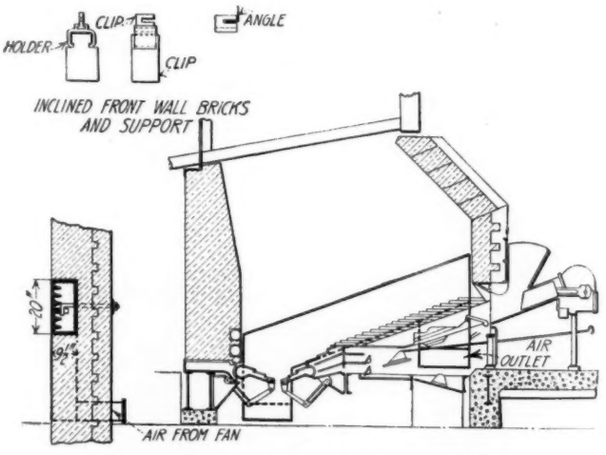
In printing-press work and where heavy, fast-moving machinery is employed, it is sometimes necessary to install a static neutralizer. This is a device that produces an alternating-current field, therefore having both positive and negative impulses. A static charge of positive sign is thereby neutralized by an impulse of opposite sign as generated by the neutralizer, consequently a static charge of negative sign is neutralized by one of positive value. This device is on the market and is used by many industries. MATHEW KING.

Passaic, N. J.

Ventilating the Side Wall Was Unsuccessful

One of the principal sources of annoyance to all stoker operators is the tendency of the clinker to stick to the side walls, which cuts down the available grate area and causes injury to the bricks when cleaning the fires.

The method illustrated was tried in conjunction with the Westinghouse stoker under a 250-hp. B. & W. type boiler, the setting being arranged as shown in the illustration. The total air for combustion was brought in from the outside of the setting underneath the boiler-room floor and conducted up along the side walls in the box as shown and finally discharged underneath the stoker. The three sides of this box were made in one casting, while the cover was made in three sections. To increase the heat-absorbing surface of the cover it



HOW THE SIDE WALLS WERE COOLED

was constructed as shown. The covers on the box were made of a good grade of cast iron.

When this method was applied and the boiler put in operation, trouble was discovered almost immediately with the cover plates burning through. Increasing the velocity of air through the boxes did not remove this difficulty, and finally the whole plan was abandoned.

The method of supporting the brick in the inclined front wall is also shown. This method was satisfactory.

Pittsburgh, Penn. L. B. BREED LOVE.

Material for Dump-Plate Bearing Bar

I have noticed, in articles in recent issues of *Power*, several references to the operation of inclined underfeed stokers. One thing essential to the successful operation of these stokers, or in fact any of the ram-type stokers, is the removal of the clinker that forms on the side wall of the furnaces.

Some of the coal shipped these days contains a high percentage of ash and clinker-forming material which accumulates on the side walls of the furnace. This formation is sometimes so hard that it is necessary to let out the fires and to cut the clinker loose with pickaxes and bars. If it is allowed to accumulate, great strain is thrown on the ram-feeding mechanism, causing breaks and compelling frequent repairs.

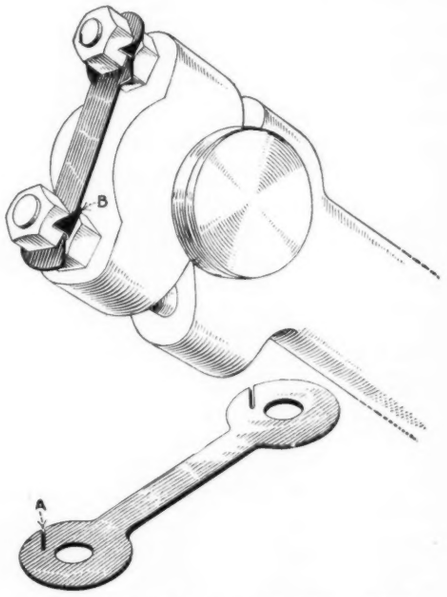
The bearing bar under the dumping grates, which supports the grate sections, is regularly supplied in $\frac{3}{4}$ x 2$\frac{1}{2}$-in. wrought iron, which sometimes bends under the heat coming from the recently dumped ashes. I have been using sleigh-shoe steel for making these bars, as it is slightly higher in carbon than the stock bars, making it stiffer under heat.

I think these bars should be made of cast iron about 1$\frac{1}{8}$ in. thick and 6 or 7 in. wide with holes properly spaced cast in for the cotter pins which hold each grate bar. It also pays to watch the hand-operated shaking extension grates to see that no ashes or clinkers get under them to make them unhook the supporting shaft and burn the ends in the fire. H. G. BURRILL.

Herkimer, N. Y.

Nut-Lock Plate

There are many ways to lock or secure nuts against slacking back, and the "lock plate" shown in the illustration is submitted, adding to the collection. The slot at *A* should be cut to within one-fourth inch of the



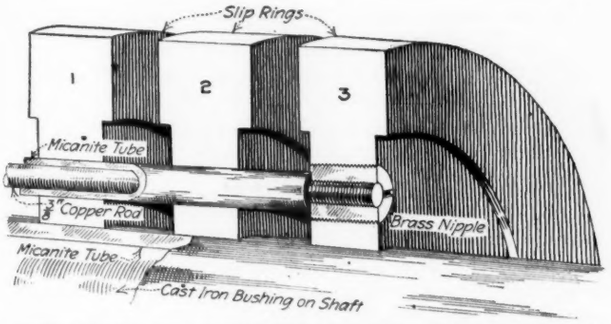
SPECIAL PLATE TO SECURE NUTS

bolt hole, and when the plate is on and the nuts up solid, the ear or tab is bent up, as shown at *B*, with a blunt chisel and a hammer. C. H. WILLEY.

Concord, N. H.

Slip-Ring Insulation Repair

The micanite insulating tube around one of the conductors to the outer slip, or collector, ring on one of our 250-kw. Westinghouse rotary converters in a traction substation broke down under the edge of the middle slip ring, resulting in a dead short-circuit across the two rings. The rings and conductors were not damaged



INSULATION ON CONDUCTOR TO SLIP RING RENEWED

much as the high-tension oil switch had only a small time lag, but the insulating tube was practically destroyed.

To remove the rings and replace the insulating tube is a big job as the cast-iron bush with all three slip rings and the conductors are assembled together before being placed on the shaft; besides, outside of the bearing on this machine there is a small rotor and slip rings for the synchronous booster which forms part of the combined set. It looked as if there was no other way but to send the armature back to the makers for repair, but this would have been a difficult job in any event and unusually so in this case since the machine is installed under a gallery with very little headroom. Besides, conditions due to the war make the smallest repair take six months or more to get through the shops, so we decided to undertake the job ourselves.

The copper conductors, four to each ring, are screwed tightly from the inside into their respective rings, and there is just room enough to screw them out clear of the ring before they foul the armature spider. As the insulation in the rings 1 and 2 and around all four conductors to the outer ring (3) was badly charred, they were screwed out and the holes in ring 3 were enlarged by means of an adjustable reamer until the regular insulating tube would just pass through and into rings 2 and 1. The holes in 3 were then tapped out with a taper pipe tap that happened to be the right size, four brass nipples were turned, threaded and screwed in and the inside bore was a good fit on their respective rods. New lengths of insulating tube were then cut and placed in position and the rods and nipples screwed tightly home. The whole connection was as solid as when new. No special tools were made for the job except a piece of flat steel cut to fit the slots cut in the nipples, across the outer end, by means of which they were screwed in, as an ordinary screwdriver was too narrow.

The job was finished and the machine on the line again the next day at noon, being out of commission 27 hours—and the repair shop was two miles away from the substation at that. D. S. REGAN.

Yorkshire, England.

An Electrical Phenomenon

I have read with much interest the article by H. S. Whiteley, "An Electrical Phenomenon," published in *Power*, Feb. 12. Similar phenomena may frequently happen, but it is not so often that they are observed, and it is very seldom they are reported and described.

The electrical effect observed was a discharge of blue sparks of static electricity produced by the friction of dry steam slightly superheated, passing through cold dry air at a high velocity, this discharge taking place where the expansion of steam was visible. Considering these phenomena from the viewpoint of the electron theory, which ascribes an atomic structure to all electrical charges, may be of interest.

When a very fine spray of water is directed on the plate of an electroscope, the leaves diverge, showing that the plate is electrified by the spray. The charge on the plate is positive and the air around the spray negatively electrified. In fact, whenever there is a splashing of water, electrification results, the two kinds of electricity being separated. Such electrical conditions can exist, for instance, at the foot of a waterfall, and it can be shown that the water is positively electrified and the air negatively. However, the kind of water and certain impurities it may contain have a decided influence upon the amount of electrification produced. It has been shown that when a drop of water is broken up into a spray while suspended in the air, the water becomes positively electrified and the surrounding air negatively. Hence, any process by which drops of water are broken up into a spray, whether by clashing against one another or in other ways, constitutes a potential source of electricity, and as soon as the strength of the field is large enough, a discharge takes place.

A few words regarding the separation of the electricities, namely, the positive electrification of the water and the negative electrification of the air:

A water molecule consists of a nucleus around which electrons are rotating. There is only one kind of electron, and this has a mass of $\frac{1}{1800}$ that of a hydrogen atom and carries a constant charge of negative electricity. The water nucleus, on the other hand, is positively charged. The two charges are equal in magnitude but opposite in sign, so that a water molecule is electrically neutral. To charge a water molecule positively means, therefore, that one of the electrons which it contains is taken out of it.

Now, when water or vapor molecules collide with the molecules of the air, electrons are pushed away from the water molecules, which by loosing electrons keep only their positive charge; namely, the charge of their nucleus. A detached electron, on the other hand, unites with a molecule of the air and then revolves about this air molecule. But when such an air molecule, which has taken on another electron, comes into contact with or near to a water molecule that has lost an electron, the formerly detached electron goes back to the water nucleus, thus establishing electrical neutrality. It is just this establishing of the electrical neutrality that we see in the form of a spark or a silent electric discharge.

A molecule that has lost or gained an electron is called an ion. A gaseous ion, in our case a water-vapor ion and an air ion, has the power of attraction through which a number of molecules that are not in the ionic state are collected around an ionic or electronic center. This fact corresponds to the observation of Mr. Whiteley that the discharge took place where the expansion of steam was visible.

By velocity measurements it has been shown that the ions in air at atmospheric pressure consist of single charges (electrons) associated with about 20 to 30 molecules of oxygen or nitrogen.

Discussion of Turbine Wreck

Allow me to comment on the wreck of the 35,000-kw. turbine of the Boston Elevated Ry., an account of which appeared in the issue of Mar. 19, page 390. At the outset let me give due and generous credit to the maker and his engineers for the prompt and frank publication of some of the details. It is just ten years ago that a 10,000-kv.-a. waterwheel generator, designed by the writer, who was then chief engineer of the electrical department of Allis-Chalmers Co., was destroyed during an overspeed test at Niagara Falls. The experience served as a most remarkable object lesson, with the result that no accident of a similar nature has occurred during the last ten years on machines with which he has had anything to do. This justifies an optimistic view in regard to the future of single-cylinder turbines of the impulse type, if the lessons from this accident are properly utilized.

The editorial remarks are judicious and fair. The disks are not the weak element. A disk construction for the largest types of turbo-generators has been developed that has marked an important advance in electric-generator design. The weakness lies in the method of holding the blades and in the distortion of the diaphragm. The use of cast steel would diminish distortion, but rotation of the diaphragm due to seizing on the shaft must be forestalled, as no material at these high speeds could resist the stresses in a disk shaped as the diaphragm is. This leads to the consideration of the advisability of greater clearance with this type of construction.

Power has rendered a public service by the publication of this accident; let us hope that this policy of frankness will find imitation in other quarters.

B. A. BEHREND.

Boston, Mass.

Tamarack Mills Power Plant

I have read with much interest the article in the Mar. 26 issue of *Power* on the Tamarack Mills power plant, and would like to call attention to an error which I think should be corrected. It is stated that "the management got a price of 92c. per barrel of 42 gal. of oil delivered." This is not correct, the price actually being $1.15 per barrel delivered.

The price you give is near that which this company is paying on their fuel-oil contract for the Jenckes Spinning Co. mill, which contract was made in 1915, and it is worthy of note that after operating with oil for a year and a half, they were willing to pay over 20 per cent. more for their oil on the new contract.

New York City. FREDERIC EWING,
Engineer, Mexican Petroleum Corp.

Inquiries of General Interest

Small Bypass Around Main Stop Valve—How can water-hammer shocks be prevented in a 6-in. steam line when the stop valve is opened very slowly and the line is drained at the discharge end through a 1¼-in. drip connection? T. P.

The line should be warmed up by means of a small bypass to control admission of steam more gradually. This will also permit of easier and safer opening of the main valve by equalizing pressure on its opposite sides.

Effect of Rocker Out of Plumb—If the rocker-arm of a Corliss valve gear oscillates ¾ in. more to one side than the other of a vertical position, what effect would it have on the operation of the steam valves? J. L.

With a rocker-arm and connections of usual length, the difference of oscillation would make no appreciable difference in adjustment or operation of the valves, provided the oscillation of the wristplate was the same on each side of the center.

Blistering of Boiler Shell—What causes blistering of a boiler shell? W. R. B.

Blistering is separation and puffing out of layers of the material that have not been thoroughly welded in the process of manufacture. When the shell is heated or cooled, the different rate of expansion or contraction causes the layers to separate. When blistering is confined to a very thin surface skin, its effect on the strength of the plate may be unimportant, but if the scaling-off process continues after the outside skin has been removed, it is an indication of defective structure of the material that may seriously impair the safety of the boiler.

Required Size of Steam Header—What should be the size of a main steam header where the sizes of pipes from five boilers are respectively 4, 5, 6, 6 and 8 in.? B. F. S.

Ordinarily, the size would be taken of an area equal to the sum of the areas of the feeders or the size of header would be

$$\sqrt{4^2 + 5^2 + (2 \times 6^2) + 8^2} = 13.3$$

or, nominally, a 14-in. pipe would be used. But for the same pressure the flow of steam in pipes of different diameters is as the square root of the fifth power of the diameters and, calling the required diameter d,

$$\sqrt{d^5} = \sqrt{4^5} + \sqrt{5^5} + 2\sqrt{6^5} + \sqrt{8^5} \text{ or } d = \sqrt[2.5]{4^{2.5} + 5^{2.5} + (2 \times 6^{2.5}) + 8^{2.5}} = 11.47 \textit{ in. diameter}$$

and a header of 12-in. pipe would answer.

Valve Travel Unaffected by Diameter of Eccentric—Will the valve travel of a slide-valve engine be affected by reducing or enlarging the diameter of the eccentric? J. B.

It would not, because the eccentric is the exact equivalent of a common crank arm in which the crankpin is sufficiently enlarged to include the shaft, so it may be placed anywhere along the shaft. The valve travel depends on the length of the arm or the distance from the center of the shaft to the center of the eccentric, commonly called its eccentricity; and just as the length of stroke with a crank is independent of the diameter of the crankpin, the length of valve travel is independent of the diameter of the eccentric.

Kilovolt-Amperes and Kilowatts—What is the difference between kilovolt-amperes (kv.-a.) and kilowatts (kw.)? W. C. L.

Alternating-current machinery and systems, excepting induction-motors, are usually rated in kilovolt-amperes (kv.-a.) and not kilowatts (kw.). In a single-phase system kv.-a. = volts × amperes ÷ 1000; in a two-phase system kv.-a. = volts × amperes × 2 ÷ 1000; and in a three-phase system kv.-a. = volts × amperes × 1.732 ÷ 1000. In all cases, kw. = kv.-a. × power factor. Kilovolt = amperes is frequently termed the apparent power, and kilowatts is called the true power, or load on an alternating-current machine or circuit. The term kilovolt-ampere is never used in reference to the rating of direct-current systems.

Wetting Down Fine Coal—In hand-firing is there advantage or disadvantage in wetting down fine sizes of bituminous coal? C. R

Wetting down makes cleaner handling, permits of better spreading and is accompanied by much less annoyance from back draft, and less combustible material is carried over by the draft into the combustion chamber. The tendency of fine coal to pack in the furnace is overcome by wetting the coal; as the steam thus generated opens the mass, the coal is burned more uniformly and more completely and with fewer cracks and large holes in the fire. The principal disadvantage is that the water used for wetting down the fuel requires heat for its evaporation into steam which is discharged to the chimney as superheated steam at atmospheric pressure; but with good spreading of the moistened fine fuel this loss will generally be more than offset by the requirement of less excess air to burn the coal on account of the more uniform distribution of draft passages through the fuel bed.

Density and Volume of Steam—What is the meaning of the density and volume of steam? A. H.

The density of a body is its mass per unit of volume, and the customary unit is pounds per cubic foot. The density of steam, therefore, is its weight in pounds per cubic foot. The density of steam or weight per cubic foot varies with the pressure. Thus, as shown by tables of properties of steam, the density of dry saturated steam at 0 gage or atmospheric pressure (taken at 14.7 lb. per sq.in. absolute) is 0.3732 lb., at 50 lb. gage (or about 65 lb. absolute) it is 0.1503 lb., and at 100 lb. gage (or about 115 lb. absolute) it is 0.2577 lb. per cu.ft. The specific volume is the number of cubic feet per pound. Therefore the specific volume is the reciprocal of the density. Thus if the weight of 1 cu.ft. of steam at 100 lb. gage is 0.2577 lb., then the volume, or space occupied by a pound, is $\frac{1}{0.2577} = 3.88$ cu.ft. per lb. Steam tables generally give both specific volume and density for different pressures.

Induction-Motor Winding Connections—Why is the secondary winding of a wound-rotor induction motor generally connected in star instead of delta? R. A.

What is true of the rotor winding may also be applied to the stator winding. Where possible both windings are connected in star. The reason for this is, that with a given weight of copper in the winding the star-connected winding is 173 per cent. as effective as the delta-connected winding. Expressing this another way, the star-connected machine requires only 58 per cent. of the copper of a delta-connected machine of the same type and capacity. The voltage generated in the secondary winding when star connected will be 1.73 times as great as that generated in the same winding when delta-connected, and the current will be in inverse proportion to the voltage. This lower current for the star connection will generally simplify the design of the controller. There are also other factors in favor of the star-connected winding such as, the coil requires a smaller number of turns, less time to place the winding on the core and the winding can be more easily insulated.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Combustion of Coal and Design of Furnaces

A review of Bureau of Mines Bulletin No. 135, which deals with the combustion of coal and the influence of furnace design upon combustion. The bulletin is one of a number issued by the Bureau and dealing with the economical utilization of the nation's fuel resources. The tests with which the bulletin deals were made in a Murphy stoker furnace of special design, at the end of which was a Heine boiler. The fuels used were Pocahontas, Pittsburgh and Illinois coal. Exceedingly interesting data relative to the combustion space or volume required for the different coals and different rates of combustion are given. Different furnaces and different fuels require different percentages of excess air to give the best results; some furnaces and some fuels may give the best results with high percentages of CO_2, whereas others may have to operate with a comparative low CO_2 content.

ABOUT a year ago, the Bureau of Mines issued a technical paper of considerable importance under the title, "Combustion in the Fuel Bed of Hand-Fired Furnaces." This was practically a virgin field, inasmuch as little or no experiments or investigations of the behavior of gases in the fuel bed of a furnace had been made. The astonishing fact revealed was that the CO_2 reached its maximum at about 4 in. above the grate in a 6-in. fuel bed, the fuel bed being presumably free of ash. All the free oxygen in the air admitted under the grate was shown to be consumed in the 6-in. fuel bed 4 in. above the grate, or 2 in. below the surface of the fuel bed. This paper was fully reviewed in *Power* for May 8, 1917, p. 640. The Bureau in carrying out its investigations made its next step the investigation of the behavior of the gases in the combustion space of the boiler furnace, and the results of these investigations are presented in Bulletin 135 by Henry Kreisinger, C. E. Augustine and S. K. Ovitz, who are the authors also of the Technical Paper No. 137.

The present bulletin, No. 135, is, we believe, the most valuable publication the Bureau has yet issued on the subject of combustion. Certainly no publication contains a similar wealth of data for the man who designs furnaces or who must operate them economically. The tests were made with Pocahontas, Pittsburgh and Illinois coals burned in a Murphy stoker (side-feed) furnace of special design. The furnace was exceedingly long, being 43 ft. 4 in. in length from the boiler to the front wall of the furnace. The firebox itself is 5 ft. wide by 5 ft. deep. The furnace is essentially a brick tunnel 3 x 3 ft. in cross-section, the stoker having 25 sq.ft. of projected grate area. The arch over the grate surface contains an air space through which air is delivered to the tuyeres supplying air over the fuel bed. Observation holes were placed every 5 ft. apart along the length of the furnace. Although the data were obtained from experiments with a Murphy furnace and are therefore particularly applicable to furnaces of that type, it is believed that they may be of value as a guide in the proportioning of other furnaces. When applying the data to other furnaces, the designer should give full consideration to the method of introducing secondary air and the facility for mixing it with the combustible rising from the fuel bed. For best results the secondary air should be introduced as near to the fuel bed as practicable, and the air should be supplied in a large number of streams at high velocity.

The gases rising from the fuel bed of a Murphy stoker contain 10 to 28 per cent. by volume of combustible. If the gases flowed through the combustion space, they mixed with the air added over the fuel bed and burned. Because of this combustion, the percentage of combustible decreases along the path of the gases, the rate of decrease being rapid at first, but slowing down as the gases move farther from the fuel bed. Inasmuch as the gases rising from the fuel bed contain 10 to 28 per cent. of combustible and practically no free oxygen, additional air must be supplied over the fuel bed to insure complete combustion. That this additional air may flow into the furnace, the pressure of gases in the furnace must be below that of the outside air. The composition of the furnace gases at various distances from the fuel bed is shown in Fig. 2. The rate of combustion in this case was 35.6 lb. of coal per sq.ft. of grate; the coal was Pittsburgh screenings. The curves show that the gases leaving the fuel bed contain over 25 per cent. of combustible gases, about 1 per cent.

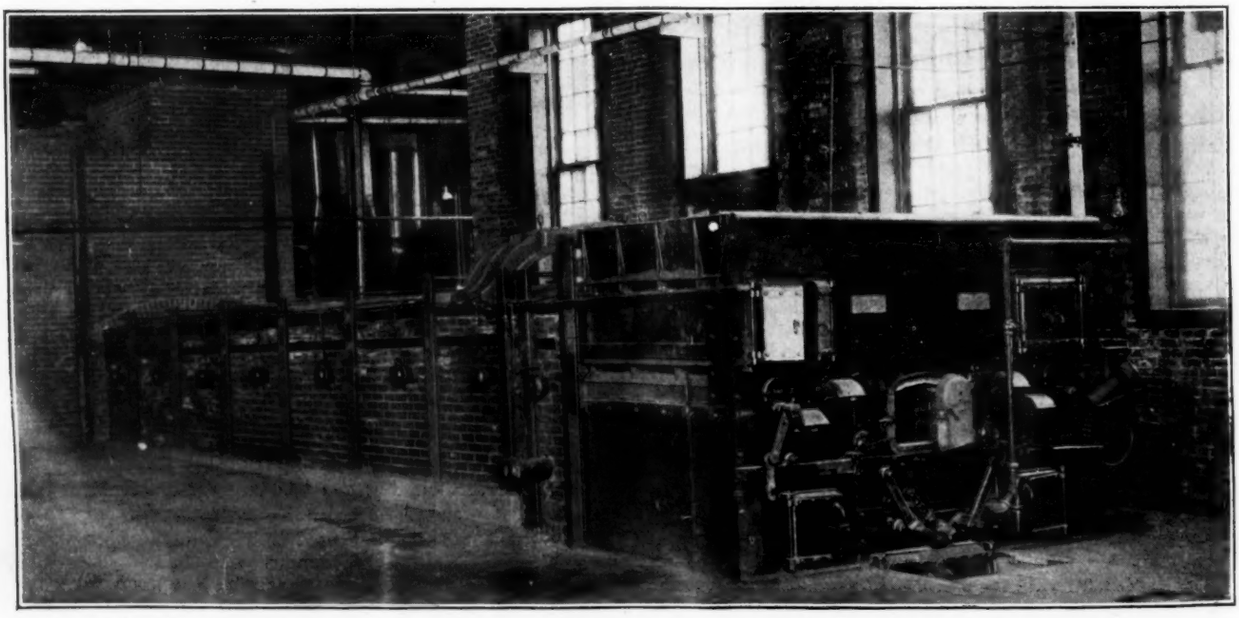


FIG. 1. EXPERIMENTAL FURNACE, SIDE-FEED STOKER; FURNACE 45 FT. BY 5 FT. SECTION

of O_2 and 7 per cent. of CO_2. Before these gases reached section *A* of the furnace, which is a point about 6 ft. from the inside front furnace wall or a point about 1 ft. beyond the firebox proper, enough air was added to make the total air supply exceed the amount theoretically required by 19 per cent. Most of this air was added through the tuyeres near the surface of the fuel bed and in a way that facilitated its mixing with the combustible gases rising from the fuel bed. In view of all that has been said about the value of high boiler settings and great furnace volume, it is interesting to note that in this figure little combustible gas is left after a distance of 13½ ft. from the grate is traveled through and by the gases. If we refer to commercial practice in furnace design, we observe that engineers have been increasing the height of boiler settings or increasing the furnace volume. Those who, five to six years ago, allowed but 8 ft. from the bottom front header of an ordinary B & W boiler to the floor line allowed 10 ft. in later design, and in still later design they have allowed as much as 12 ft. It would seem, from the experiments told of in this bulletin that inasmuch as the combustion rate greatly influences the furnace volume required, and inasmuch as high rates of combustion are required to carry peak loads, the 12 ft., which probably represents the maximum in modern practice, is still short of the most desirable height. Of course, volume alone is not sufficient in commercial boilers, and the authors mention this fact. There also should be provisions for mixing the combustible gases and the air for combustion.

In the most recent installations of the "W" type Stirling boilers by the Detroit Edison Co., the distance from the bottom of the middle drum to the dump plate is 33 ft. It is 28 ft. in the old Delray boilers. Vertically baffled boilers are now being set 12 ft. from floor to front headers.

The authors say that the length or volume of the combustion space required for practically complete combustion seems to depend chiefly upon the percentage of excess air, the rate of combustion and the kind of coal.

Influence of Excess Air

Comparison of different curves plotted by the authors show that for the same rate of combustion when the excess air is large, the proportion of combustible gases is less at any given cross-section (distance from the firebox) of the furnace and the combustion is practically complete in a smaller combustion space than when the excess air is small. Investigations show that as the size of combustion space increases, the minimum losses are obtained with a lower excess of air and a higher percentage of CO_2 in the furnace gases. The minimum losses in the furnace having a small combustion space are much larger than the minimum losses in the furnace equipped with a large combustion space. However, with a large combustion space the minimum losses extend over a much smaller range of excess air than they would with a smaller combustion space. This means that with a furnace having a large combustion space, more skill is required to keep its performance within the narrow range of minimum losses or maximum efficiency than to operate a small furnace at its best. With the furnace having a small combustion space a variation of 50 to 100 per cent. in the excess of air makes little difference in the performance of the furnace. However, the maximum efficiency of the furnace having the large combustion space is so much higher than that of the furnace with the small space that there is little doubt left as to which is preferable.

It is interesting to note that at the surface of the fuel bed the combustible gases represent 35 to 65 per cent. of the total heat value of the coal. This means that under ordinary operation of the side-feed furnace about one-half of the total heat in the coal is developed in the fuel bed, the other half being developed in the combustion space. Among other factors, it depends upon the size of the combustion space how much of the 50 per cent. of heat left in the combustible rising from the fuel bed is developed. There then follow in the bulletin a number of curves showing the relation between the completeness of combustion and the length and volume of the combustion space; also the effect of the excess of air and the rate of firing on the completeness of combustion at the various sections of the combustion space.

Figs. 3 and 4 (Figs. 29 and 30 of the bulletin) may be used for determining the size of the combustion space required for given conditions in the following manner: Suppose that it is desired to design a furnace that will burn Illinois coal at the rate of 40 lb. per sq.ft. of grate per hour with 50 per cent. excess of air, and with an incomplete combustion of only 2 per cent. of the heat in the coal as fired. For the solution of this problem the left half of Fig. 3 can be used. Refer to the group of curves designated by 2 per cent. (undeveloped heat) at the left margin. From the intersection point of the horizontal line of 40 lb. rate of combustion with the curve of 50 per cent. excess of air, a vertical line is followed to the bottom of the figure, where, in the second scale, the size of the combustion space is found to be 5.8 cu.ft. to every square foot of grate. The first scale indicates that the length of gas traveled for this

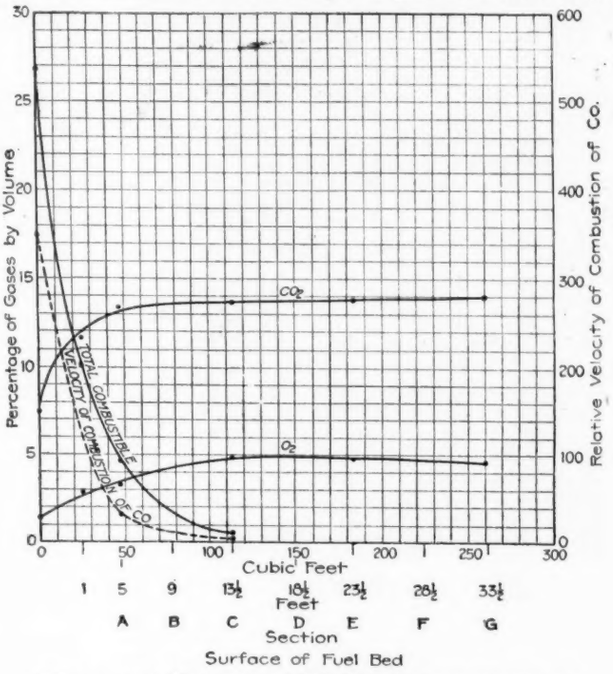


FIG. 2. PROGRESS OF COMPOSITION OF GASES AT VARIOUS DISTANCES FROM THE FUEL BED

condition should be about 18 ft. The first scale at the bottom indicates that, with the experimental furnace, about 145 cu.ft. of combustion space was needed to satisfy the given conditions, the space extending to within 1 ft. of section *B* of the furnace, which is at a distance approximately 10 ft. from the front wall of the furnace or firebox.

If Pocahontas coal is to be burned under the same conditions, the required size of the combustion space is obtained from the group of curves designated by 2 per cent. undeveloped heat in the right half of the same figure. From the intersection point of the horizontal line a rate of combustion of 40 lb. with the curve of 50 per cent. of excess air in the vertical line is followed to the bottom of the figure, where the second scale indicates that about 3.2 cu.ft. of combustion space is needed for every square foot of grate area and that the length of the gas path should be about 10 feet.

When Pittsburgh run-of-mine coal is to be burned, it is found in the same manner from the left half of Fig. 4 that the best results can be obtained with a rate of volume to grate area of about 3.9 to 1 and an average length of gas travel of about 12 feet.

Thus, the three coals, Pocahontas, Pittsburgh and Illinois, require 3.2, 3.9 and 5.8 cu.ft. of space per square foot of grate, respectively, to burn 40 lb. of coal per square foot of grate per hour, 50 per cent. excess of air and incomplete combustion of 2 per cent. of the total heat in the coal as fired. According to the right half of Fig. 4, when burning Pittsburgh screenings, only about 3.1 cu.ft. of

combustion space is required per square foot of grate to burn the coal with the same results. This is about the same combustion space required per square foot of grate to burn Pocahontas coal.

When considering the volume of combustion space, it is well to add that the length of the gas travel is probably an important factor. It seems that a long narrow combustion space is more efficient in burning the gases than a short wide one having the same cubical space. In the long narrow space, the gases travel with a higher velocity,

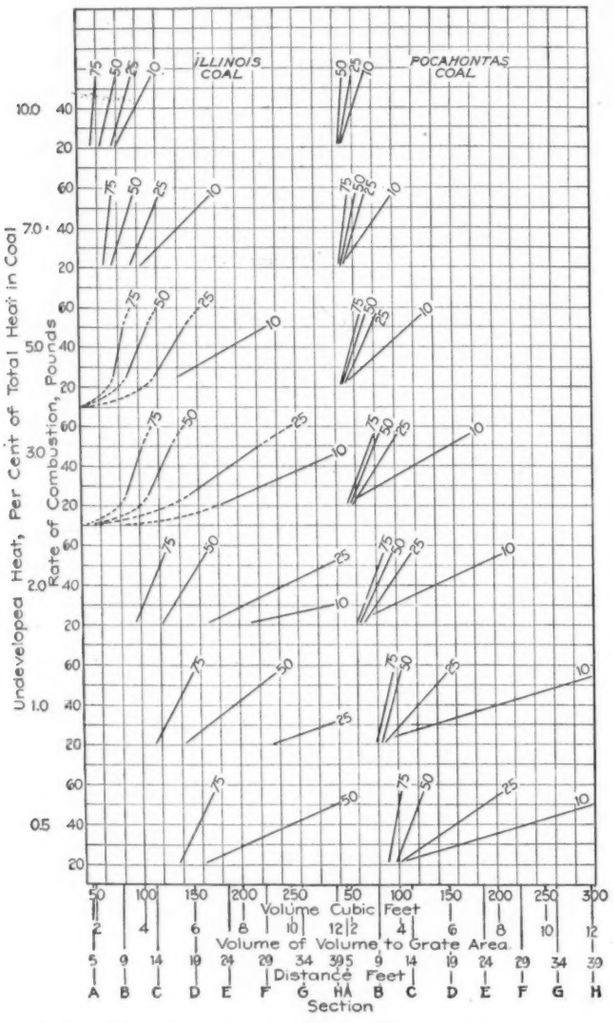


FIG. 3. COMBUSTION VOLUME REQUIRED FOR ILLINOIS AND POCAHONTAS COALS

Shows the relation between the required combustion volume, given completeness of combustion, rate of firing and excess air. Figure on each curve indicates percentage of excess air.

which promotes mixing and therefore quickens the combustion. In the short wide space, the gases remain the same length of time, but travel slower. On account of this slower movement, the gases are less agitated and tend to travel in stratified streams. Therefore, there is less mixing and the combustion is slower. It is advisable that in using the data of Figs. 3 and 4 in designing a furnace, the path of the gases be made nearly as long as in the experimental furnace as practicable.

Table V of the bulletin (here Table I) is one which undoubtedly should be of practical value to the designer of furnaces or to the man responsible for furnace alterations. The table gives the size of the required combustion space for the three coals and several sets of conditions indicated by columns 1, 2 and 3 of the table. Examination of the values in columns 4, 5 and 6 shows that the size of the combustion space does not increase in direct proportion to the percentage of volatile matter in the coal. The increase in the combustion space from Pittsburgh to Illinois coal is much larger than the increase from Pocahontas to Pittsburgh coal. Roughly speaking, under the same conditions Pittsburgh coal requires about 20 per cent. larger combustion space than Pocahontas coal, while Illinois coal requires about 40 per cent. larger combustion space than Pittsburgh coal. That the size of the combustion space does not increase in direct proportion to the percentage of volatile matter in the coal is shown graphically in another curve of the bulletin designated as Fig. 31, which curve does not appear here. If the relation of the size of the combustion space to the percentage of volatile matter were a direct proportion, the relation would be represented by a straight line. The curves are far from straight lines and become more and more curved as conditions of less complete

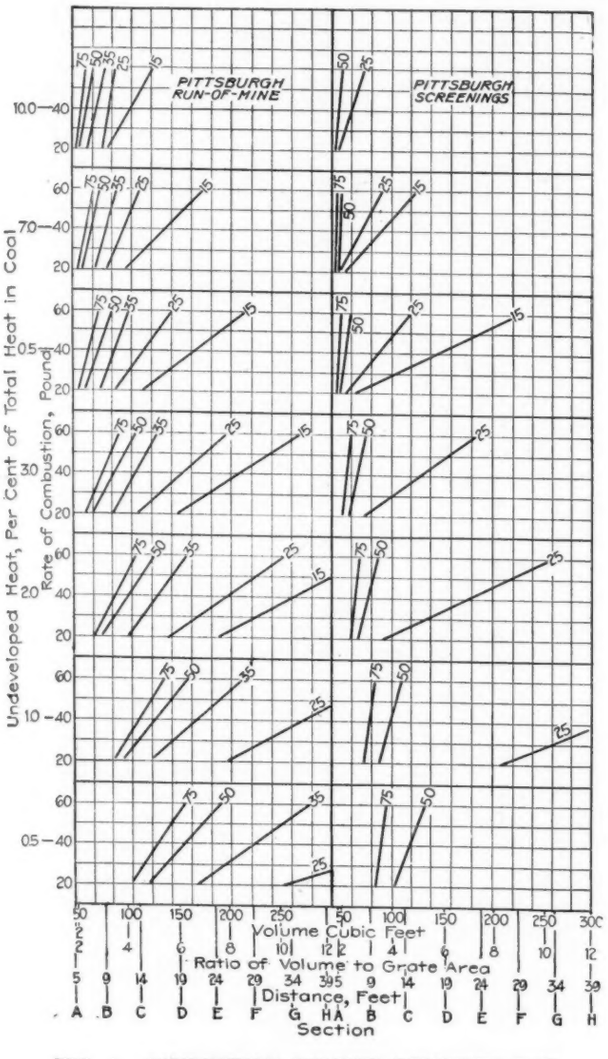


FIG. 4. COMBUSTION VOLUME REQUIRED FOR PITTSBURGH COALS

Figures on curves denote excess air

combustion are considered and the combustion space becomes smaller. However, in the opposite direction toward complete combustion the curves seem to approach a straight line.

That the size of the required combustion space under ordinary degrees of completeness of combustion does not vary in direct proportion as the quantity of volatile matter even if the quality of the latter remains constant can be deduced from Table V by comparing the two rates of combustion of the same coal. Thus, when the rate of combustion is doubled, the quantity of the volatile matter distilled per unit of time is doubled. However, to burn this double quantity of volatile matter with the same excess of

air to the same completeness, the combustion space is increased only about 20 per cent.

The following paragraph is quite significant in view of the experience that we have had in the burning of coal in a practical way. It explains why some settings fail in one place and succeed in another.

The quality of the volatile combustible, as far as the ease of burning is concerned, is perhaps best expressed by item 6 in Table I, showing the ratio of volatile carbon to available hydrogen. These values were obtained by dividing the volatile carbon by the available hydrogen and are probably fair indicators of the burning qualities of the coals. The amount of volatile carbon was computed by subtracting the amount of fixed carbon from that of the total carbon. The available hydrogen is equal to the hydrogen content on a moisture and ash-free basis minus one-eighth of the oxygen content. The ratio shows that the volatile matter of the Pittsburgh coal contains nearly twice as much carbon, and that of the Illinois coal three times as much carbon, as the Pocahontas coal. These ratios indicate the probability that in burning Pocahontas coal, the volatile combustible is distilled mostly as light gases which are easily burned in the diluted furnace atmosphere, whereas,

TABLE I. COMBUSTION SPACE REQUIRED FOR POCAHONTAS, PITTSBURGH AND ILLINOIS COALS

Completeness of Combustion, per Cent. of Undeveloped Heat	Rate of Combustion, Lb. per Sq. Ft. of Grate per Hr.	Excess of Air, per Cent.	Cubic Feet of Combustion Space per Sq.Ft Grate		
			Pocahontas	Pittsburgh	Illinois
1	2	3	4.	5.	6.
5	50	50	2.7	2.9	4.3
3	50	50	3.2	3.7	5.3
2	50	50	3.6	4.4	6.3
1	50	50	4.0	5.6	8.9
0.5	50	50	4.8	6.8	11.9
5	25	50	2.0	2.2	3.5
3	25	50	2.3	2.7	4.35
2	25	50	2.7	3.1	5.1
1	25	50	3.4	4.0	6.2
0.5	25	50	4.0	5.0	7.1

in burning Illinois coal the volatile combustible leaves the fuel bed mostly as heavy hydrocarbons in the form of tars, which, in the diluted oxygen of the furnace atmosphere, are first decomposed into the lighter hydrocarbons and carbons, the latter being precipitated as soot. This mixture of soot, tar and gases burns slowly and requires a large combustion space for its complete combustion.

In general, the higher the carbon content in the carbon-hydrogen compound the more time is required for their combustion. Therefore, it may be expected that as the ratio of volatile carbon to available hydrogen increases, the size of the combustion space required for a given degree of completeness also increases. In a rough way, when nearly complete combustion is desired, the size of combustion space varies directly as the product of the quantity and quality of the volatile matter as the two are given in items 1 and 6 of Table IV (here Table I). As the combustion becomes less complete, the curve showing the relation between this product and the size of the combustion space is farther from a straight line. Distillation at low temperatures favors the formation of light hydrocarbons of the paraffin series, which contain more hydrogen and less carbon than the hydrocarbon of the aromatic group, which are distilled at high temperature. The hydrocarbons of the paraffin series are more stable at high temperatures and, on account of their higher hydrogen content, are more likely to burn completely without depositing soot. It requires one molecule of oxygen to burn completely one atom of carbon, whereas one molecule of oxygen burns completely four atoms of hydrogen. Thus, of two compounds having the same number of atoms in a molecule, the one having more hydrogen requires less oxygen for its combustion, and therefore, in the same concentration of oxygen, will burn more readily. The authors here go into quite a detailed statement relative to the composition of the various hydrocarbons, and the discussion shows the advantage of distilling volatile matter at low temperatures, producing mostly paraffin or other hydrocarbons of this group. The furnace should be so designed that distillation takes place at low temperature. After the volatile matter is distilled, air should be added and the mixture thus passed through a hot chamber, especially with the smoky coal, for the reason that slow and uniform heating of the coal occurs when the coal is highest in volatile contents, or in other words, when it is admitted to the furnace distillation taking place in a low temperature and in the presence of oxygen. With most of the common types of mechanical stokers the distillation of volatile matter occurs in the presence of oxygen, whereas in hand-fired furnaces distillation is almost in entire absence of oxygen, all of the latter being consumed as it passes through the fuel bed. Even if there should be some tendency to decomposition with the mechanical stokers, the presence of large percentages of oxygen at the point of distillation makes it possible for the hydrocarbons to react with oxygen before the deposition of carbon can really take place. High temperatures, such as exist in boiler furnaces and in the absence of oxygen, promote the decomposition of all hydrocarbons, including methane, the lightest of the paraffin series, one of the products of decomposition being soot. When methane is burned with insufficient air supply, it burns with a yellow flame and deposits soot. It should, therefore, be burned with some excess of air and with provision for obtaining a good burning mixture, otherwise soot will be deposited.

The authors devote considerable space to a discussion of soot and its formation. The subject is interesting and important enough to warrant mention here. Tests show that the combustible matter rising from the fuel bed was roughly 12 per cent. in the form of tar and soot. The coal was Pittsburgh screening. Immediately at the surface of the fuel bed the quantity of tar is largest, but decreases rapidly as the gases pass through the combustion space. On the other hand, the soot increases during the first foot of gas travel. In general, an increase in the rate of combustion and in the excess of air is accompanied by a decrease in the quantity of soot, particularly in the quantity of tar. With all rates of combustion and all excess of air, there is a large decrease in the quantity of tar and a moderate increase in the quantity of soot, during the first foot of the length of gas travel.

This decrease in the quantity of tar and increase in the quantity of soot seems to indicate that the volatile matter leaves the fuel bed as heavy hydrocarbon mostly in the form of tar. These tars are decomposed by the high furnace temperature and in the absence of oxygen into soot and lighter, more gaseous hydrocarbons. The process of

TABLE II. CHEMICAL CHARACTERISTICS OF THREE COALS TESTED

	Pocahontas Coal	Pittsburgh Coal	Illinois Coal
1. Volatile matter in moisture and ash-free coal, per cent	18.05	34.77	46.52
2. Fixed carbon in moisture and ash-free coal, per cent	81.95	65.23	53.48
3. Carbon in moisture and ash-free coal, per cent	90.50	85.7	79.7
4. Volatile carbon in moisture and ash-free coal, per cent	8.55	20.47	26.22
5. Available hydrogen in moisture and ash-free coal, per cent	3.96	4.70	3.96
6. Ratio of volatile carbon to available hydrogen, per cent	2.16	4.35	6.6
7. Oxygen in moisture and ash-free coal, per cent	3.32	5.59	10.93
8. Nitrogen in moisture and ash-free coal, per cent	1.19	1.73	1.70
9. Moisture accompanying 100 per cent. of moisture and ash-free coal, per cent	2.53	2.88	22.07
10. Volatile matter times ratio of volatile carbon to available hydrogen (product of items 1 and 6)	39.0	151.00	307.00
11. Ratio of oxygen to total carbon, in moisture and ash-free coal	0.0367	0.0652	0.137
12. Total moisture in furnace per lb. of coal reduced to moisture and ash-free basis, lb	0.409	0.501	0.70

the decomposition of the hydrocarbons very likely consists of a number of consecutive reactions each step of which is accompanied by the deposition of soot and formation of lighter hydrocarbons. This process of decomposition is complicated by the presence of CO_2, which reacts with the soot and combustible gases and is itself reduced to CO. The decomposition and reduction proceed toward the simple gases CO and H_2.

The length of time in which the tars are decomposed into soot and gases is short. At the rate of combustion of 30 lb. per sq.ft. of grate per hour, the gases travel with a velocity of about 10 ft. per second. As most of the tar disappears during the first foot of the gas travel from the fuel bed, the time taken for the decomposition of the tar is about one-tenth of a second. This high rate of decom-

position is undoubtedly due to the high temperature near the fuel bed, which in the test was probably not less than 1500 deg. C., or 2732 deg. F. This is a dazzling white heat. In the light of the preceding discussion it appears that soot, which is the main constituent of visible smoke, is formed at or very near the surface of the fuel bed and not at the place where the furnace gases strike the heating surface of the boiler. The heating surfaces merely cool the gases surrounding the soot, thereby preventing its combustion. The formation of soot at the surface of the fuel bed is caused by the high furnace temperature and absence of oxygen. It is possible that if oxygen was present in sufficient quantity at the time of distillation of volatile matter, the heavy hydrocarbons would burn directly to products of complete combustion, CO_2 and H_2O, without first decomposing and depositing soot. After the soot has once been formed, it is difficult to burn it in the atmosphere of the furnace. This fact has been observed by many investigators, and some of the early writers on combustion even considered soot as noncombustible. At present no support can be found for this extreme view. As a matter of fact all combustible substances burn slowly in an atmosphere of highly diluted oxygen, but in the case of soot this slowness is much more pronounced. The reason for the very slow combustion of soot in highly diluted oxygen probably lies in its complex molecular structure. The chances of the molecule of soot finding the 12 molecules of oxygen presumably required to burn it are small.

Cracking of Tar in the Furnace

Tar exists in the furnace in the form of vapor, an ideal condition for cracking. The small globules present a large surface for absorption of heat from the gases and hot furnace walls and are quickly heated to a high temperature which favors the formation of carbon.

On account of the complex nature of tar, a great many reactions are involved in its decomposition. In general, the cracking is similar to that of hydrocarbon gases, but many more compounds are involved, and the result is a complicated equilibrium among a large number of hydrocarbons. Little experimental data are available on equilibrium and the velocity of these reactions; however, the high temperature in the furnace and the fact that the tar is in a state of subdivision favor rapid cracking and the formation of large amounts of carbon. This view is supported by the results shown in Fig. 44 of the bulletin, but not given here. The greatest amount of tar is found with a larger proportion of soot. The amount of tar and the gases decreases rapidly as the distance from the fuel beds increases; at an average distance of 5 ft., the tar has nearly disappeared. The velocity of combustion of hydrocarbon is faster than the velocity of decomposition; therefore, combustion will take precedence over decomposition for this reason. Air supplied over the fuel bed should be admitted as near to the surface of the bed as possible and mixed with the hydrocarbons so that they will be burned before they are decomposed by heat and form smoke, which is difficult to burn in the diluted oxygen of the furnace.

Pages 125 to 134 are devoted to an interesting explanation of the chemistry of combustion as carried on in a boiler furnace. These pages are omitted in this review.

What the authors have to say relative to the future method of using bituminous coal is interesting. Difficulty in burning bituminous coal in industrial furnaces is due almost entirely to the volatile matter because this leaves the fuel bed as gases and tars and must be burned in the combustion space of the furnace. Unless enough air is introduced immediately at the surface of the fuel bed and thoroughly mixed with the volatile combustible, the tars and more complex combustible gases are quickly decomposed or cracked into soot and simple gases. The soot thus formed is difficult to burn in a dilute furnace atmosphere and is likely to pass out of the furnace as black smoke, particularly if the furnace is hand-fired. The fixed carbon is easy to burn because it stays on the grate. It burns partly to CO_2, partly to CO, which in turn can be burned to CO_2 with additional air introduced above the fuel bed. The authors here point out that the various measures tried by individuals and cities to prevent smoke have, on the whole, done but little to solve the problem. In view of what is known of the chemistry of fuels and the possible advancement of such knowledge in the near future, it is questionable whether the method used in attacking the smoke problem was the best as regards fuel economy, the authors say. The persistence of smokiness in burning bituminous coal shows that there is room for improvement in methods of burning. The volatile matter of bituminous coal would have greater economic value if converted into gas or liquid fuel than if burned under steam boilers. Under present market conditions heat in the form of coal gas brings eight to sixteen times the price of an equivalent amount of heat in the form of coal. Gas is an extremely convenient fuel and can be used to advantage for many purposes, such as cooking, lighting and heating buildings, municipal lighting and in some industrial plants for obtaining a uniformly high temperature and clean products of combustion. The residue from the coking coals should find a ready market for househeating and for steaming purposes.

By the application of proper processes, it seems possible to reduce a large part of the volatile matter to liquid, of which an appreciable percentage could be obtained in the form of light oils suitable for motor fuels. Benzol has been obtained at byproduct plants for many years without any special effort to produce it. There is no doubt that with well-developed methods the yield of benzol and similar oils could be greatly increased. The value of heat in the form of motor fuel is twenty to thirty times as great as that of heat in the form of coal.

As the supply of bituminous coal is enormous, the uses of the oil are practically unlimited and the margin of profit in the conversion is large, it would seem that the development of highly productive methods would be rapid. By itself, the coke residue from such plants would have considerable commercial value, and if its price were made equivalent to that of coal, it would doubtless find a wide margin for house-heating and steaming purposes. The higher the percentage of volatile combustible the higher will be the commercial value of the coal. The time may come when our views of the relative values of different coals will change, and we shall consider anthracite as of minor importance as compared with the high-volatile bituminous coals.

The authors say that reports from Europe indicate that after the war the world will be informed of some extraordinary developments in the utilization of bituminous coal in certain countries, and that these developments will be of striking importance to the manufacturers of the United States.

The bulletin is one that every engineer concerned with furnaces, stokers and combustion should include in his library. It may be had free by addressing the Director, Bureau of Mines, Washington, D. C.

Engine Wreck from Unusual Cause

An item in the Swiss engineering journal, *Schweizerische Bauzeitung*, tells of the breakage of a cylinder head due to an unusual cause, bad lubricating oil.

The rear cylinder cover of a 500-hp. uniflow steam engine was forced out during operation but not by waterhammer, the usual cause. The cause of the break was found to be in the bad quality of the cylinder oil (tar oil). The deposit from this very thick oil, which also contained various mechanical impurities, accumulated on the piston and cylinder-head surfaces in a continually thickening crust which finally filled the entire clearance space at the back end of the cylinder and in time began to strike, compressing the substance more and more solidly and finally forcing the cylinder head out.

A saving of 25 per cent. in ammonia consumption by ice and refrigeration plants will mean several million pounds annually for munitions. A pound of ammonia will make 20 hand grenades. Ice cream and refrigeration concerns are asked to do everything in their power to stop waste and leakage of ammonia, and report on the first of each month what is being done to conserve it.

Steam-Electric Power-Plant Design*

By A. S. Loizeaux

IN THIS lecture the speaker generalizes on principles that may be used as a guide in power-plant design. It is most important for an engineer to consider and understand principles rather than individual facts, because every engineer's work presents problems of its own, which can be best solved only by applying general principles to decide the best design for the case.

It is necessary to pass the circulating water through screens located in the intake tunnel, to eliminate foreign materials. Friction through the screens will be a considerable item. The drop in head should be modest, perhaps not more than one or two feet, in order to reduce the lift required by the circulating pump. Stationary screens may be satisfactory where the water is exceptionally good, but where any considerable amount of foreign matter exists, revolving screens are required. Stationary screens were used at Westport, but they became clogged at frequent intervals. In some cases clogging resulted in a three-foot drop of head through the screen. This would take place in a few hours, the resultant pressure damaging the screens by bending. On raising the screens they would be found stopped with foreign matter and, in some cases, several wheelbarrow loads of fish and crabs. Revolving screens have eliminated these difficulties and give entire satisfaction. They are not operated continuously, but only at such intervals as the conditions require. The washing of these screens is automatically done by means of a pipe with high-pressure water impinging on the screen after it turns over the top guide.

Bunker Capacity Needed

The coal bunker should have a storage capacity for at least 48 hours' operation or more to provide for interruption of the coal supply. Automatic coal scales are now generally used to feed all stokers. Boiler-house records can then readily check the coal used by the plant, the duty of each boiler, and an efficiency test can be made on any boiler when desired.

The water-tube boiler practically holds the entire field in large power-plant work. Both straight-tube and curved-tube boilers are used.

Boiler horsepower has been by common agreement taken to be 10 sq.ft. of heating surface, this being approximately the heating surface required in old designs to produce one boiler horsepower of 34.5 lb. of water evaporated from and at 212 deg. F.

It has been found, however, that boiler capacity has been limited only by furnace capacity under the boiler and that with modern types of stokers the boiler capacity can be increased to double or even three times its normal rating. For the sake of uniformity, the normal boiler horsepower remains as before.

Economical boiler-house design today must provide for stokers, as may be readily seen by considering the investment required for a definite output. A hand-fired boiler will develop rated boiler capacity continuously, and under the best conditions may reach 150 per cent. A good stoker will deliver continuously twice rated boiler capacity and over peaks three times rated capacity, thus producing with the same boiler twice the output of the hand-fired boiler. It is evident that this is equivalent to cutting boiler-house investment nearly in half by the use of stokers.

The boiler setting required for underfed stokers must be higher than for hand-fired boilers, a space of ten feet from the stoker surface to the tubes being required for thorough combustion.

Draft through the fuel bed is provided by blowers in connection with stokers as before mentioned. It is not feasible to provide sufficient draft by this means, however, to carry the gases through the boilers, because a positive pressure in the furnace as compared with the atmosphere would produce a movement of the heated gases through the boiler setting to the outside and would soon destroy even the best firebrick. A slight negative pressure should be maintained in the combustion chamber, and this negative pressure or suction will therefore be increased throughout the several passes of the boiler and through the breechings to the stack. To provide this draft or negative pressure a chimney must be provided.

The draft available with given stack temperature is roughly proportional to the height of the chimney except that friction cuts down this proportion. The capacity in cubic feet per minute is roughly proportional to the cross-section of the chimney. Steel chimneys are sometimes used, but their upkeep is greater than for brick chimneys. A steel chimney should be lined all the way to the top to prevent corrosion on the inside, and it requires frequent painting on the outside. Masonry chimneys are made of perforated radial tile to conserve heat and material, and they are designed to be stable at various sections throughout their height. Their upkeep is negligible.

Mechanical Exhausters Unsatisfactory

Mechanical exhausters have been tried in lieu of chimneys, but have been unsatisfactory owing to the lack of reliability of fans working in high temperature. In designing breechings three points should be kept in mind: (1) Connections to stack should be as short as possible; (2) as few as possible changes in direction and use bends where this is unavoidable; (3) practically uniform speed of gas, requiring cross-section proportional to the gas carried.

A three-pass boiler has a distinct advantage in draft connections as compared with four-pass boilers because of lower friction and larger passes available.

Superheat of 100 to 200 deg. F. is used to improve the economy of generation. This also avoids water in the steam delivered to the turbine. The use of superheated steam requires the use of cast steel for all valve bodies and fittings, as cast iron under the greater heat will expand or grow until sometimes rupture occurs.

Pipes for high-pressure steam are made of wrought steel of about the same grade as boiler steel. The size of piping is determined by the speed of steam through piping to supply normally a maximum load. A few years ago engineers were using velocities of 10,000 ft. per min. and higher for normal load. It was found that these velocities produced a greater drop in pressure than was expected, the loss occurring possibly to a large extent in bends and fittings. Our present practice is to allow 8000 ft. per min. for normal load. When overloads are carried higher velocities may be produced, but as these periods are of short duration, they will not be serious.

Heaters Should Be Well Above Pumps

The use of a feed-water heater with water carrying solid matter in solution often acts as a purifier in causing this solid matter to separate out and be deposited, in the heater, as its temperature is raised. Heaters should be located well above boiler-feed pumps to provide positive heads. This requirement is due to the fact that hot water cannot be lifted by suction without breaking the water column due to liberation of steam. The temperature of water vapor at different negative pressures as compared with atmospheric pressure determines the critical point for any condition of suction with hot water.

The day when an engineer designs his own engine is passed. Today manufacturers are asked for bids and specifications on units of specified size. Alternative designs are often available, some being more efficient and costly than others. The choice of proper equipment then is determined by the cost of output when fixed cost as well as operating cost is included. In general the choice between high-efficiency, high-cost apparatus and low-cost, low-efficiency equipment is determined by the load factor, or hours of service per year. The higher the load factor on apparatus or plant the more will the effect of higher efficiency make itself felt. A plant that is held simply as stand-by in case of emergency and may operate only a few hours per year is evidently a case where lower cost would justify the use of low-efficiency apparatus.

*Abstract from a lecture delivered at the Johns Hopkins University, Baltimore, Md., Mar. 13, 1918, as one of the J. E. Aldred Lectures on Engineering Practice.

It is important that apparatus should be uniform in any plant to reduce the necessary stock of repair parts and make it simpler for the operating forces. There is a temptation in adding to a power plant to use apparatus, such as boilers, stokers and pumps, and different things, because of some slight advantage in design or cost. Some plants might almost be termed museums, due to the variety of apparatus. The designer should use the utmost care in first choosing type and make of equipment and then adhere to the standard set throughout the plant unless some great advantage unquestionably makes it wise to change. One advantage of standardizing is the greatly reduced engineering cost of adding to a plant by using additional duplicate units.

One of the fundamental lessons of practical power-house experience is the imperative need of spare equipment. One boiler in every five or six should be spare to provide for cleaning and repair and also for repairing the stokers. A spare turbo-generating unit is required in a power house whether the load calls for one or more units. The practical capacity of a plant is therefore its continuous capacity with one unit out of service. Thus a plant designed to carry 100,000 kw. should have the following number of units:

Each Unit	Number of Units	Total Rating, Kw.	Safe Capacity One Unit Out of Service, Kw.
10,000 kw	11	110,000	100,000
15,000 kw	8	120,000	105,000
20,000 kw	6	120,000	100,000
25,000 kw	5	125,000	100,000

It will be seen that the larger the individual unit the greater capacity must be provided for spare, unless the number of units becomes large, and then more than one would be required for spare. The same principle of spare equipment is applied to the use of auxiliaries, the common design being to provide for two circulating pumps with each generating unit, also two air pumps and two condensate pumps. These auxiliaries are frequently supplied with both steam and electric drive for the double purpose of insuring reliability and also of controlling at will the amount of exhaust steam available for feed-water heating.

Those Damaged German Ships

When the history of this audacious war is fully written, there should be no more interesting chapter than that which deals with the interned German ships and their reappearance in a few months as auxiliary transports of the United States Navy. And this notwithstanding the damage inflicted upon them by Prussian orders was such as was calculated to keep them out of service for two years or what the Germans had figured as the period within which the war would terminate.

Thirty-seven German ships of 700,000 aggregate tons had their 74 engine cylinders so broken that repairs within any reasonable time seemed out of the question. The biggest ships appeared to call for new castings entirely beyond the capacity of any foundry works in the United States.

When the Shipping Board got down to close estimates, it figured the repair bill at $2,600,000 and time required 18 to 24 months. But American enterprise, combined with American invention, concentrated capital and industrial organization in large units accomplished the job in six to eight months at an expense of only $273,000. Every one of these ships has been for many weeks most effectively in Uncle Sam's service except possibly the "Armenia," lost off the Irish coast.

The Navy Department, says the Boston *News Bureau*, has figured that the saving in time at the going rate of tonnage had a value of not less than $240,000,000. One of the first ships tackled had four cylinders broken and it was estimated that 18 months would be required for repairs. In two months the engines were turning over, and in less than three months the ship was finished and ready for sea.

Indeed, the striking feature of the whole situation is the fact that the repairs on all the ships were made within the time required to overhaul the ships, clean their bottoms and otherwise make them ready for sea. The Germans had all their labor for their pains. What is also well-nigh incredible, the ships are stronger than before and the largest of them are more economically operated and are actually working better in the American than in the German hands.

Take the "Vaterland" for example. She is the biggest and most beautiful thing afloat. Stood up on Broadway, she would tower 200 feet above the Woolworth Building. She has 18 decks, 18 elevators, 5 kitchens, 530 clocks all timed from the main bridge, hot and cold water in every room, and many miles of piping, wiring and electric controls. This vessel was damaged as directed by the government to insure her being out of commission for at least two years. There were no foundries on this side of the ocean that could give the "Vaterland" new cylinder castings of 70 tons each, and no drydock that could receive her on this side of the ocean except at the Panama Canal.

It was found that the United States Steel Corporation had developed just the right wire soldering with the proper mixture of manganese and that the railroad repair shops around New York had developed the electric welding process of the General Electric Co. to a higher efficiency than anywhere else in the world. The railroad shops and the General Electric Co. were able to furnish the apparatus and the crews to repair the machinery of the "Vaterland" within the time required for general overhauling and cleaning of the ship's bottom by a half-dozen submarine divers who, among other things, took 280 bushels of oysters off the "Vaterland's" bottom.

The "Vaterland" was equipped with both Curtis and Parsons turbine engines, but the Germans have never been able to work them to full efficiency. Indeed, on the last trip to this country under German engineers, the "Vaterland" was able to use only part of her machinery. The American engineers adjusted everything, improved the machinery and the draft to her 46 boilers, improved the piping and valves and sent the giant forth in a few months at above a 21-knot speed and using 200 tons of coal a day less than before.

The Germans had figured that the "Vaterland" could never be repaired in the United States and if repaired was such a complicated piece of mechanism that it could never be operated by Americans or any new official staff. The officers of the big German ships have to be in training at least a year with their ships during construction. Now on the "Vaterland" in place of five German captains of the unlimited license class, there is but one American captain; and instead of a chief engineer and five assistant engineers, there is just one American chief engineer, and he is only 32 years of age.

The General Electric Co., the New York Central and the Erie Railroads all coöperated with electric workers and electric welding devices and what it was estimated would require five months on this ship was done in ten days. Thirteen breaks or cracks in the "Vaterland's" cylinders were mechanically patched by the electric welding system and made stronger than before, yet without a single rivet having to be put through the 3½ inches of metal.

It is said that Indian coal is the cheapest in the world. The coal now being worked is comparatively near the surface and labor is cheap. One of the difficulties in mining seems to be that a sufficient supply of labor is not always available when wanted, as the majority of the workmen follow the vocation of agriculture as well as mining and return to their homes during the periods of sowing and reaping. During the last 10 years the use of machinery has been rapidly extending, especially at the larger collieries. About 145,000 persons are employed in coal mining.—*Gas and Oil Power.*

The War-Savings Stamps project is, in reality, a two-billion dollar loan launched among the masses of the people and is intended for the benefit of those who cannot afford to buy the larger bond issues. It is a most democratic plan in that it reaches the entire population from coast to coast, men, women and children, rich and poor alike, and there certainly is not a person in this prosperous land so humbly placed that he or she cannot buy a 25c. Thrift Stamp as a tribute of loyalty toward Uncle Sam.

A. I. E. E. Discusses Single-Phase Induction Motors

The American Institute of Electrical Engineers held its 339th meeting in the Chamber of Commerce Building, Pittsburgh, Penn., Tuesday evening, Apr. 9, and in the Engineering Societies Building, New York City, Friday evening, Apr. 12, 1918. At New York a buffet dinner was served prior to the meeting, under the auspices of the New York Membership Acquaintance Committee.

The New York meeting was called to order at 8:15 by Vice President B. A. Behrend. Two papers were presented: "No Load Conditions of Single-Phase Induction Motors and Phase Converters," by R. E. Hellmund; and "A Physical Conception of the Operation of the Single-Phase Induction Motor," by B. G. Lamme. Mr. Lamme presented his paper in abstract and illustrated his remarks by diagrams on the blackboard. The paper covers a method of studying the action of the single-phase induction motor, which the author has found to be very convenient from the educational standpoint. It is based on the assumption of two equal and opposite rotating primary magnetomotive forces combined with a synchronously rotating secondary magnetomotive force, such as would be produced by direct-current excitation. A comparison is made between a two-motor unit consisting of two similar polyphase motors coupled together and connected for opposite rotation and the straight single-phase induction motor.

In the absence of the author Mr. Hellmund's paper was presented in abstract by A. M. Dudley, who explained its important details by the use of a number of lantern slides. In this paper methods are shown and formulas derived for the determination of the fields, the stator and rotor magnetizing currents, and tertiary voltages for phase converters and single-phase induction motors. The paper is of considerable length, occupying some 85 pages of the proceedings, and involves considerable mathematical analysis. However, it is arranged so that it can be read to good advantage without going through the major portion of the mathematics. The importance of the subject was demonstrated by the large number of prominent engineers who took part in the discussion. These were B. A. Behrend, Dr. Michael I. Pupin, E. F. W. Alexanderson, L. W. Chubb, Alexander M. Gray, C. A. M. Weber, Prof. C. F. Scott and Selby D. Harr.

One of the most prominent features brought out at the meeting was the lack of some simple method of presenting the action of the single-phase induction motor. The discussion of the paper was closed by B. G. Lamme.

Test of World's Largest Turbine a Success

Electrification of the Coast section of the Chicago, Milwaukee & St. Paul Ry. took a long step forward recently with the turning over for the first time of its big turbine generator, the largest in the world, at the White River, or Lake Tapps, generating station of the Puget Sound Traction, Light and Power Co., which has the contract for furnishing the power.

The turbine into which water was turned recently is one of 25,000-hp. capacity, and it constitutes the third unit in the White River plant. This plant is on the east side of Stuck River valley, five miles from Auburn, Wash., between Seattle and Tacoma, and is the largest and most important of the hydro-electric plants of the Puget Sound Traction, Light and Power Co. and one of the most remarkable in the world. It is built at the base of a high plateau between the Stuck and White Rivers, on which Lake Tapps is situated. White River was diverted above Buckley and emptied into the series of lakes of which Lake Tapps is the largest, and which form the natural storage reservoir. The water is taken from this reservoir through penstocks of inch steel 8 ft. in diameter at the intake and 6½ ft. at the power house. The penstocks are 2500 ft. long, and the water is fed to the turbines at a head of 465 feet. There are three units, each of one turbine, directly connected by shaft to the generator it drives. The first two turbines are of 20,000 hp. each. The new turbine is of 25,000 hp. and is the largest in the world. The total capacity of the plant with the added unit is 65,000 hp. This gives the traction company a combined capacity of all its plants supplying Seattle of 110,000 horsepower.

The Milwaukee road will require a little more than 50 per cent. of the additional power. The current will be delivered to the railroad at a voltage of 100,000, alternating current, and transformed into direct current at a voltage of 3000 for use on the motors of the Milwaukee electric locomotives. The traction company's contract with the railroad calls for the delivery of 10,000 kw. of 100,000 volts, alternating current. The railroad has yet to install substations and overhead trolley wires on the division between Othello and Tacoma. The trolley poles are now being placed in position, though operation electrically will be delayed for some time owing to a shortage in some classes of equipment. When this section of the Milwaukee electrification is completed, the road will be operated by electricity between Tacoma and eastern Montana.

War Convention of the Machinery, Tool and Supply Industry

The enormous problem of manufacturing and supplying machinery and tools sufficient for the carrying out of the Government program for the production of ships, shells, guns and aircraft will be the subject considered at the great "War Convention" of the machinery, tool and supply industry of the country to be held in Cleveland the week of May 13.

One thousand men who are bearing the brunt of the unprecedented demand for machinery will gather from all parts of the country to lay out a plan, with the aid of Government officials, to keep the great munition program going at top speed. The big war convention will be a joint meeting of four great national associations—the American Supply and Machinery Manufacturers' Association, the National Supply and Machinery Dealers' Association, the Southern Supply and Machinery Dealers' Association and the National Pipe and Supplies Association—which will meet together in order to coördinate their efforts toward one goal—"more ships, more shells."

"No industry has a greater responsibility at this moment than the machinery men," said H. W. Strong, president of the National Supply and Machinery Dealers' Association. "We must have men, but behind the men must be ships and munitions, and behind the ships and munitions, machinery —more machinery—still more machinery. We are in this fight to a finish. The Germans have convinced us that the only way out of the war is straight through, and the American machinery industry is ready to carry on to a knockout."

The part played by drills in the game of war is shown by the computation that 70 drilled holes are required in every 3-inch shrapnel shell, in every rifle 90, machine gun 350, torpedo 3466, war plane 4089, war truck 5946, war ambulance 1500, 3-inch field gun 1280, gun caisson 594, and anti-aircraft gun 1200.

"'Carry on' will be the watchword of the convention," said R. F. Valentine, president of the Maufacturers' Association.

New Power Development in Pennsylvania

Public-utility companies at Philadelphia, Penn., and vicinity are conferring with Government representatives for the development of the electric generating stations in the Lehigh Valley section of the state, supplemented by the construction of new transmission lines to connect with existing high-tension systems in Pennsylvania, New Jersey, New York and Delaware.

The proposed project, devised as a war measure and arranged with an idea of fuel conservation, will place the resources and ability of the different companies at the dis-

posal of the Government. The Philadelphia Electric Co., Philadelphia, and the Electric Bond and Share Co., New York, the latter operating electric plants at Harwood Mines, Penn., and neighboring sections in this mining district for light and power service, are the two principal utility companies interested.

It is proposed to build extensions to a number of the existing generating stations to provide an increased output of at least 100,000 hp. Following this two or three new plants will be constructed, with total generating capacity of about 100,000 kw. The different stations will be tied in with a network of transmission lines, and a new high-tension system will be constructed to Philadelphia. Here it is planned to connect with the present lines of the Philadelphia Electric Co. and those of the Public Service Electric Co., operating in New Jersey, as well as with the system of the American Railways Co., which operates lighting and power properties in Pennsylvania, South Jersey and Delaware. The plan also includes a proposition to connect the new system with the lines of the Public Service Electric Co. at Newark and vicinity, and with New York City power lines.

Estimates of cost are now being made and different phases of the work investigated. While it is possible that the cost of the enterprise will be financed by the Government, this has not as yet been decided. The entire plan is designed to be of mutual benefit and not to the individual interest of any of the particular companies. William Potter, Pennsylvania State Fuel Administrator, and Charles E. Stuart, public-utility engineer for the Fuel Administration in the state, are representing the Government in the development plans.

Rights in Waters of Streams

A late decision of the North Dakota Supreme Court, handed down in the case of McDonough vs. Russell-Miller Milling Co., 165 Northwestern Reporter, 504, shows that an owner of land bordering a river has no unqualified right to object to use of waters of the stream by an upper landowner for manufacturing purposes.

Plaintiff complained that defendant's use of the stream by returning waters to it somewhat contaminated in their use rendered plaintiff's use less valuable, especially for the purposes of harvesting ice. But the court found that his rights, as governed by the following stated legal principles, had not been invaded:

The right of a riparian owner to have a natural stream continue to flow through or by his premises in its natural quantity and quality is subject to the right of each riparian owner to make reasonable use of the waters of the stream while remaining on his land. "Manifestly, running streams cannot be used for commercial, manufacturing or agricultural purposes and retain their pristine clearness and purity."

The question whether a reasonable or unreasonable use of the water is being made, having regard to the common rights of others, is to be determined by the circumstances of each particular case, due consideration being given to the character and size of the water course, its location and the uses to which it may be applied, as well as the general usage of the country in similar cases. . . Upon the question of reasonableness of the use by the upper proprietor, the character and extent of his business, as well as the use to which the lower proprietor is putting the water, may be taken into consideration.

Waste from Water Leakage

Water wasters cause unnecessary pumping that requires the use of 100,000 tons of coal annually in Chicago, in pumping and sterilizing 2½ times as much water as the consumers actually use, the waste and leakage amounting to more than the combined consumption of Milwaukee, Boston, Cleveland and St. Louis. The coal required for pumping this waste during one year amounts to more than enough to heat all its public schools during the winter. This useless pumping adds about half a million dollars a year to the operating expenses. Furthermore, three and a half million dollars is spent annually in an attempt to keep the plant adequate for the extravagantly excessive service, and even this amount is not sufficient. If the waste could be stopped, no further additions need be made for more than thirty years to come. The waste of water so reduces the pressure in the mains that for more than three-fourths of the area of the city it is less than half of that recommended by the National Board of Fire Underwriters, and in only one of the 35 wards does it equal the recommended pressure. With approximately 2,500,000 population, Chicago is pumping into its water mains 14 per cent. more water than New York receives by gravity (with no pumping costs) for the use of a population of 5,500,000. It supplies more water than any other water-works system in the world.

The startling facts here given are derived from a report entitled "The Water-Works System of the City of Chicago," that has just been published by the Chicago Bureau of Public Efficiency. The purpose of the report is to make public, and emphasize the enormous waste, and the undoubted increase in this waste of public funds which will occur unless radical methods are carried out for greatly reducing it.—*Municipal Journal.*

Thrift-Stamp Selling Machine

The War Savings Committee of Greater New York recently announced the placing of an order for 1500 Thrift Banks. These are really Thrift-Stamp selling machines which not only sell stamps for 25 cents but also register each sale.

The New York committee feels that this machine will greatly increase the sale of Thrift Stamps, and facilitate the handling of the stamps by merchants. The machines are meeting with great popularity everywhere. Frank Vanderlip, chairman of the National War Savings Committee, recently placed his stamp of approval upon them, expressing his hope that they would be adopted generally by the committees all over the country. Closely following Mr. Vanderlip's approval, the Treasury Department was so greatly impressed that it decided to put up the stamps in rolls of one hundred each at a little less than one cent per roll, in order to facilitate the feeding of the machine.

These machines are ideal for factories on payday or for any place where money changes hands or people congregate. Their use does not eliminate the personal solicitations, which are necessary if the War Savings Stamp campaign is to be a success. The first shipment of the New York Committee's order has already been started, and it is expected that within a few days everyone in New York will be able to purchase Thrift Stamps from this automatic salesman of Uncle Sam.

Full particulars regarding the machine will be furnished on application to the New York War Savings Committee, 51 Chambers St., New York City.

Conflicting Water Claims

In view of the fact that practically all Connecticut streams available for municipal water supply were long ago utilized for water power, either directly or through connecting waters, it must be supposed that a municipal charter, amended in 1901 and reaffirmed in 1909, empowering the municipality to condemn the waters of certain streams, contemplated appropriation of waters of streams that might already be used for water-power purposes at least when such water powers are not already employed in some other public use at the time of the proposed taking by the municipality. Respondent power company, although authorized to exercise the flowage rights of individuals and to use a brook to generate electricity, and although possessed of rights in the stream acquired for that purpose, is not entitled to defeat condemnation of waters of the stream by a municipality for water-supply purposes under statutory authority; the power company's property not being presently devoted, nor about to be devoted, to public use, within the general principle of law that property already appropriated to one public use cannot thereafter be condemned for an inconsistent public use. (Connecticut Supreme Court of Errors, East Hartford Fire District vs. Glastonbury Power Co., 102 Atlantic Reporter, 592.)

New Publications

FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS. By Engineers of the Harrison Safety Boiler Works, Philadelphia, Penn. Cloth; 4¾ x 7 in.; 270 pages; 213 illustrations. Price $1.

The material contained in this book is both informative and timely. It is not original, but is a compilation of statements, tables and charts from various sources, the references being given in the majority of cases. Taken as a whole, it forms an authoritative treatment of the entire range of subjects relating to combustion and the economical management of steam-boiler plants, and is of value to owners, managers, engineers and firemen. The work is divided into five sections, the first of which deals with coal, its classification, analysis, heating value, purchase by specification, washing, storage and weathering, together with a brief notice of oil and gas as fuels. The second section takes up the chemistry of combustion, air required, grates, hand-firing methods, stokers and their operation, clinker, draft, stack proportions, draft gages, dampers, flue-gas analyses, excess air and smoke prevention. The third section treats of heat transmission, economizers, air heaters and superheaters, relation between heating surface and boiler capacity, boiler setting, firebrick, soot, scale, softening feed water and feed-water heating. The fourth section covers heat absorbed by boiler, heat losses, efficiencies, boiler capacity and boiler trials. The fifth section discusses various arrangements of auxiliaries with regard to their effect upon feed heating and also describes the Polakov functional system of boiler-room management.

Personals

Robert S. Blake, formerly representing the Condit Electric and Manufacturing Co., of Boston, in Pittsburgh, is now district manager of the Chicago office of the Duquesne Electric and Manufacturing Co., at 230 So. LaSalle St.

Engineering Affairs

The Bridgeport (Conn.) Section of the A. S. M. E. will meet on Apr. 24, and the New Haven Branch will meet on May 10.

The American Water-Works Association will hold its annual convention at the Planters Hotel, St. Louis, Mo., May 13, 1918.

George A. Orrok talked on Tuesday evening, Apr. 17, to the Student Branch of the American Society of Mechanical Engineers at Yale, on Internal Combustion Engines.

The Association of Iron and Steel Electrical Engineers announces the following meetings: The Cleveland Section on Apr. 27 at the Union League Rooms of the Statler Hotel. T. F. Bailey, president of The Electric Furnace Co., will present a paper on "Electric Soaking Pits, Annealing and Heat-Treating Furnaces and Furnaces for Melting Nonferrous Metals." The Philadelphia Section, at the Majestic Hotel, on May 4, at which H. A. Lewis and W. H. Burr will present a paper on "Electrically Operated Door Hoists for Openhearth Furnaces." In addition to this Major William A. Garret will address the meeting on "Some of My Observations in France." The Pittsburgh and Cleveland District Sections will hold a joint technical session at Youngstown, Ohio, on May 18, and make an inspection of McDonald and Ohio Works, Carnegie Steel Co.

Miscellaneous News

The Commercial and Industrial Museum of Montreal, Canada, has been established as an annex to the Faculty of Commerce, to furnish Canadian manufacturers and dealers information of interest to them in their business, and as a medium of advertising to Canadian and American customers. Manufacturers and exporters may get free space to exhibit their goods by communicating with the Museum at 399 Viger Ave., Montreal, Canada.

Concrete Ships—Edward N. Hurley, chairman of the United States Shipping Board, has recommended to the Secretary of the Treasury that the sum of $50,000,000 be authorized, of which some $15,000,000 shall be appropriated for the acquisition or establishment of plants suitable for concrete shipbuilding, or of materials essential thereto, or for the enlargement or extension of such plants as are now or may hereafter be acquired or established, and for the cost of constructing, purchasing, requisitioning or otherwise acquiring such concrete ships.

The House Naval Appropriation Bill for the year ending June 30, 1919, as reported from the Committee on Naval Affairs, contains numerous large appropriations for improvements and extensions to central power plants and distributing systems as follows: Navy Yard, Portsmouth, N. H., $150,000; Boston, Mass., $75,000; New York, $200,000; Philadelphia, Penn., $300,000; Norfolk, Va., $300,000; Naval Academy, $325,000; Naval Station, New Orleans, La., $280,000; Mare Island, Calif., $100,000; Puget Sound, Wash., $200,000; Marine Barracks, Peking, China (power plant), $25,000. Other items of general interest are as follows: For an investigation of fuel oil and gasoline adapted to naval requirements, $60,000; for aviation for naval purposes, $188,042,969; for expenses in connection with the civilian Naval Consulting Board, $100,000.

Two Applications for Permits to appropriate water which, combined, represent an outlay of $6,000,000 were recently filed in the office of State Engineer Lewis, Salem, Ore., by H. S. McGowan, of Pacific County, Washington. The application asks for a year in which to prepare plans and specifications of the proposed projects, and it is believed that the initial step that has been taken is in preparation for a possible legislation in Congress throwing open the waters to public development.

One application is to appropriate the waters of the Deschutes River to the extent of 45,000 cu.ft. a second. The proposed project is in Sherman and Wasco Counties, the river forming the boundaries between the two counties, and the purpose stated in the application is hydro-electric development and transmission for manufacturing purposes and general use. A dam which is being planned would be 118 ft. high, 800 ft. long at the top, 300 ft. long at the bottom, built of reinforced concrete with wasteway. The estimated cost of the project is $2,000,000.

The other application states the same purpose. The project proposed is in Jefferson County and would require 3500 cu.ft. per second. The estimated dimensions of the dam necessary are 236 ft. high, 420 ft. long at the top, 90 ft. long at the bottom, built of reinforced concrete of the overflow type. The estimated cost of the project is $4,000,000.

The Puget Sound Traction, Light and Power Co., Seattle, Wash., will have, when its present development is completed, hydro-electric plants supplying Seattle and Tacoma with power for industrial needs with a combined capacity of 107,997 hp. divided as follows: White River, 63,000; Electron, 18,667; and Snoqualmie Falls, 26,330 hp. The steam plant's capacity will aggregate 38,264 hp., 24,000 at the Georgetown plant, 6667 at Western Avenue, 4267 at Post Street, and 3330 in the Tacoma steam plants. The total capacity will then be 146,261 hp., which will be ample for some time. To the traction company's development must be added the hydro-electric and steam auxiliary plants of the Seattle municipal electric system, having a combined capacity of 24,000 hp. The White River or Lake Tapps development is the largest power project in the Northwest, and is still far from fully developed. It was made by diverting the flow of White River at a high point in its channel into three natural lake beds lying high on the plateau overlooking the lower White River valley. Twelve dams were constructed to create a reservoir and channel cut from the upper river to this reservoir. Before the work was done the company had to purchase 36 miles of riparian rights extending on both sides of the stream from the point of divergence 28 miles down to the point where the water again enters the river bed. By this means 2,500,000,000 cu. ft. of water is impounded. The station is located on the valley level of the lower river, and the water enters the penstocks from an outlet on top of the plateau.

Business Items

The Power Turbo-Blower Co., will move, on May 1, from 17 Battery Place to 347 Madison Ave., New York City.

The Whitlock Coil Pipe Co.'s Philadelphia office is now at 1009 Commercial Trust Building. William Wilcox, the district engineer, is in charge of the office.

NEW CONSTRUCTION

Proposed Work

N. H., Portsmouth—The Bureau of Supplies and Accounts, Wash., D. C., will soon receive bids for furnishing under Schedule No. 1766, at Navy Yard, here, 13,000 ft. plain rubber air hose for pneumatic tools and 5000 ft. 2½ in., rubber lined, cotton, fire hose; Schedule No. 1767, 1000 ft. 12½ in. engineers department hose, 1000 ft. bright finish, brass, wood hose.

Vt., Middlebury—The Hortonia Power Co., Gryphon Corner Bldg., Rutland, is having plans prepared for the erection of a 1-story, 28 x 90 ft. power house here. Grover & Connor, Rutland, Engrs.

Vt., Springfield—The Colonial Light and Power Co. has had plans prepared by W. S. Barstow Co., Inc., Engr., 50 Pine St., New York City, for the erection of a substation, garage, etc. G. F. Sanderson, Supt.

Mass., Boston—The U. S. Government plans to build a power plant. Estimated cost, $35,000.

Mass., Grafton—The State Commission on Mental Diseases is in the market for a new boiler to cost $8000; also setting up and connecting same with a battery and into the stack to furnish light, heat and power.

N. Y., Brooklyn—The Edison Electric Co., 360 Pearl St., has had plans prepared for alterations and additions to its 1-story power house on Gold St. G. L. Knight, 13 Willoughby St., Arch.

N. Y., Brooklyn—The Kings County Electric Light and Power Co., 360 Pearl St., has applied to the Public Service Commission for permission to issue $1,000,000 bonds; the proceeds will be used to build additions and make improvements to its plant. W. F. Wells, Gen. Mgr.

N. Y., Dunkirk—City plans to install a new lighting system in the business section. Estimated cost, $5000.

N. Y., Jamestown—The Crescent Tool Co., 200 Harrison St., soon receives bids for a 1-story, 100 x 200 ft., power house on Harrison St. Estimated cost, $200,000. Equipment including 1500 kw. gas driven generators and 1500 kw. steam turbine driven generators will be installed. F. A. Shoemaker, Builders Exchange, Buffalo, Engr. Noted Apr. 9.

N. Y., Mohawk—W. W. Wotherspoon, Supt. of Public Works, Capitol, Albany, is having plans prepared for the erection of hydraulic power plants under Barge Canal Contract No. 176.

N. Y., Utica—The Adirondack Power Co., Glen Falls, plans to build a power house near here. Estimated cost, $100,000. W. A. Buttrick, Glens Falls, Mgr.

N. J., Mountain Lakes—The Board of Education, Hanover Township, plans to install a new heating system in the local school building.

N. J., Plainfield—The International Power Corporation plans to build a power plant in Freeville near here.

N. J., Trenton—The Crescent Insulated Wire and Cable Co., Olden and Taylor St., will soon receive separate bids for an entire steam heating system, electric elevator and electric lighting system. Peuckert & Wundr, 310 Chestnut St., Philadelphia, Arch.

Penn., Birdsboro—The E. & G. Brooke Iron Co. plans to build a 6 mi. electric transmission line from here to iron and copper mines at Elverson to supply current for the electrical equipment used in the mine.

Md., Myersville—City plans to install an electric lighting plant and a water-works system.

Ga., Dallas—The Dallas Utility Co., recently incorporated, plans to install an electric power plant on Pumpkin Vine Creek, Paulding County. J. S. Boges, Mgr.

Ohio, Bryan—The Village plans to expend about $40,000 for extensions to its electric lighting and water-works systems.

Ohio, Cleveland—City has had plans prepared by the City Engineer, for the construction of a 3-story, 169 x 175 ft. electric lighting plant. Estimated cost, $256,000.

Ohio, Cleveland—The Steel Products Co., 2196 Clarkwood Rd., has had plans prepared for the erection of a 1-story, 50 x 60 ft. heating plant to be erected on Cedar Ave. Estimated cost, $50,000. Burchard, Roberts & Wales, Engr., 622 Swetland Bldg., receives bids until May 18. Noted Apr. 16.

Ohio, East Cleveland—(Cleveland P. O.)—The Board of Education, Shaw High School Bldg., plans to install a low pressure boiler for steam heat, also a central heating plant in Technical High School on Prospect Ave. W. H. Nicklas, Engr., 1900 Euclid Ave., receives bids for same.

Ohio, East Liverpool—City is receiving bids for the installation of a new lighting system on Main St. from 3rd to 18th St.

Ohio, Holgate—The Pleasant Light and Water Co., recently organized with $10,000, will take over the municipal plant and install additional equipment in same.

Ohio, Springfield—The Springfield Light, Heat and Power Co. has petitioned the State Utility commision for authority to issue $100,000; the proceeds will be used to purchase boilers and mechanical equipment.

Ind., Connersville—The Rex Manufacturing Co. has had plans prepared for the erection of a 1-story, 58 x 120 ft. power house. E. C. Bacon, Engr., 617 Merchants Bank Bldg., Indianapolis, is receiving bids for same.

Mich., Flushing—The Hart Milling and Power Co. is having preliminary plans prepared for the erection of a power plant, pumping station, etc. L. T. Sayre, Pres.

Wis., Brodhead—The City Council will receive bids until Apr. 30 at the office of R. F. Leger, Attorney, for the erection of a brick power plant. Noted Apr. 9.

Wis., Cedarburg—The Cedarburg Canning Co. has had plans prepared for the erection of a 2-story 20 x 80 ft. boiler and storage room addition to its plant. Estimated cost, $10,000. W. F. Helgen, Arch.

Wis., Fond du Lac—The F. Ruening Leather Co. is having preliminary plans prepared by E. Kottke, Engr., for the erection of a power plant.

Wis., Sheboygan—The Badger State Tanning Co., 3 Water St., has had plans prepared for the erection of a 1- and 2-story, 76 x 130 ft. power house, machine shop, etc. Juul & Smith, Engr., 805 North 8th St., receiving bids. Noted Jan. 22.

Wis., Superior—The Superior Iron Works, 3rd St. and Grand Ave., plans to build a 2-story, 60 x 96 ft. boiler shop. Estimated cost, $5,000.

Iowa, Keokuk—The E. I. duPont de Nemours Co., Wilmington, Del., is improving and building an addition to its power plant at Mooar. Estimated cost, $200,000. C. K. Weston, Wilmington, Publicity Agt.

S. D., Sherman—Bim Bros. has been granted a franchise for an electric lighting system.

Tex., Bremont—The Calvert Water, Ice and Electric Light Co., Calvert, plans to install an electric lighting system here and extend its transmission line from here to Calvert. A. E. Stoltz, Calvert, Ch. Engr.

Okla., Prague—City voted $15,000 bonds for electric lights. Noted Feb. 5.

Okla., Yale—City election soon to vote on bond issue for electric lights

Que., Montreal—O. P. Tremblay, 291 Prud 'Homme Ave., Notre Dame de Grace, is in the market for 20-25 hp. electric motor and three 7 or 2-10 hp. transformers.

Ont., Sudbury—The Water and Light Committee is in the market for an electric pump with 12,000 gal. capacity and a 175 hp., 2 phase induction, direct drive, 220 volts, a.c. motor. W. J. Rose, town clk.

Ont. Toronto—The Veterinary Specialty Co., Ltd., 1595 Dundas St., W., is in the market for a 100 hp. boiler, a 75 hp. engine and 1-ton power elevator.

Man., Winnipeg—The Board of Control plans to build a gas plant here. Address A. Puttee, Controller.

B. C., Nelson—The Town plans to build an electro melting plant. A. Thomas, city engr.

CONTRACTS AWARDED

Mass., Boston—The New York, New Haven and Hartford R.R., New Haven, has awarded the contract for the erection of a 1-story, 20 x 140 ft., electric battery building, C. W. Murdock, 185 Church St., New Haven.

Mass., Cambridge—The Cambridge Electric Light Co., 46 Blackstone St., has awarded the contract for the erection of a 1-story, 44 x 69 ft. addition to its boiler house, to the J. F. Griffin Co., 17 Milk St., Boston. Estimated cost, $20,000.

Mass., Springfield—The United Electric Light Co., 73 State St., has awarded the contract for improvements to its plant, to Stone & Webster, 147 Milk St., Boston. Estimated cost, $300,000. Work includes installation of new switching equipment throughout the plant; also a 25,000 hp. steam turbine.

N. Y., Brooklyn—The U. S. Government has awarded the contract for a 1-story, 48 x 80 ft. steel power house to be erected at the Navy Yard, here, to the Westinghouse, Church, Kerr Co., 37 Wall St., New York City.

N. Y., Rochester—The Board of Contract and Supply has awarded the contract for the erection of a power plant, to A. Friederich & Sons Co., 710 Lake Ave.

N. Y., Yonkers—The National Sugar Refining Co., Main St., has awarded the contract for the erection of a boiler house, to Lynch & Larkin, 127 Downing St. Estimated cost, $40,000. Noted June 26.

N. J., Newark—The Northern Leather Works and Produce Co., Inc., 377 Broadway, New York City, has awarded the contract for the erection of a power house, to H. W. Franklin, 110 Fort Green Pl., Brooklyn.

Penn., Allentown—The Allentown Bethlehem Gas Co., a subsidiary of the United Gas Improvement Co., Broad and Arch St., Philadelphia, has awarded the contract for the erection of a generator and boiler house addition, to the Ochs Constr. Co., 442 Wire St.

Penn., Grove City—The Grove City Creamery Co. has awarded the contract for the erection of a 3-story power plant, to Rose & Fisher, 1719 Pennsylvania Ave., Pittsburgh. Noted Oct. 23.

Penn., Philadelphia—The Atlantic Refining Co., 3144 Passyunk Ave., has awarded the contract for alterations and improvements to its power house, to Metzger & Fisher, Otis Bldg. Estimated cost, $11,300.

Md., Linthicum—The Consolidated Gas, Electric Light and Power Co., Lexington St. Bldg., Baltimore, has awarded the contract for the erection of a 26 x 40 ft. addition to its power station, to the Coggswell Koether Co., 406 Park Ave., Baltimore. Noted Mar. 26.

Va., Norfolk—The Virginia Railway and Power Co. has awarded the contract for the erection of a 1-story, 50 x 100 ft substation, to Nicholas & Linderman, Seaboard Bank Bldg. Estimated cost, $11,700. Noted Oct. 7.

W. Va., Parkersburg—The Parkersburg Iron and Steel Co. has awarded the contract for the erection of a 1-story, 30 x 42 ft. power house, to the Rust Eng. Co., Farmers Bank Bldg., Pittsburgh, Penn. Estimated cost, $12,000.

Ohio, Alliance—The Dougherty Operating Co. is building a large plant here to supply current to two cities. Estimated cost, $2,225,000. M R. Bunt, Ch. Engr.

Ohio, Lorain—The American Ship Building Co. is building a large power plant here. Estimated cost, $200,000.

Ill., East St. Louis—B. Gratz, c/o the American Manufacturing Co., 1026 South 11th St., St. Louis, Mo., has awarded the contract for the erection of a 1-story, 51 x 88 ft. power plant, to L. H. Gron, Benoist Bldg., St. Louis, Mo. Estimated cost, $40,000. Noted Dec. 4.

Wis., Eau Claire—The Eau Claire Boiler and Laundry Co. has awarded the contract for the erection of a boiler house and laundry, to The Hoeppner and Bartlett Co.

Minn., Duluth—The McDougall Duluth Shipbuilding Co., 15th Ave., has awarded the contract for the erection of a large boiler shop, to McLeod & Smith, 705 Sellwood St.

Ore., Portland—The Northwestern Electric Co. has awarded the contract for the erection of an auxiliary steam plant, to C. C. Moore & Co., San Francisco, Cal.

Calif., Richmond—City has awarded the contract for furnishing a 5-ton electric crane at the wharf, to the Cyclops Iron Works, 837 Folsom St., San Francisco, cost, $75,000; furnishing an electric motor, to the United Electric Vehicle Co., 1239 Sutter St., San Francisco, $4383.

THE COAL MARKET

Boston—Current quotations per gross ton delivered alongside Boston points as compared with a year ago are as follows:

ANTHRACITE

	Circular Apr. 18, 1918	Indivtdual Apr. 18, 1918
Buckwheat	$4.60	$7.10—7.35
Rice	4.10	6.65—6.90
Boiler	3.90	.....
Barley	3.60	6.15—6.40

BITUMINOUS

Bituminous not on market.

Pocohontas and New River, f.o.b. Hampton Roads, is $4, as compared with $2.85—2.00 a year ago.

*All-rail to Boston is $2.60. †Water coal.

New York—Current quotations per gross ton f.o.b. Tidewater at the lower ports* are as follows:

ANTHRACITE

	Circular Apr. 18, 1918	Individual Apr. 18, 1918
Pea	$4.90	$5.65
Buckwheat	4.45@5.15	4.80@5.50
Barley	3.40@3.65	3.80@4.50
Rice	3.90@4.10	3.00@4.00
Boiler	3.65@3.90	.....

Quotations at the upper ports are about 5c. higher.

BITUMINOUS

	F.o.b. N. Y. Gross	Mine Price Net	Gross
Central Pennsylvania	$5.06	$3.05	$3.41
Maryland—			
Mine-run	4.84	2.85	3.19
Prepared	5.06	5.05	3.41
Screenings	4.50	2.55	2.85

*The lower ports are: Elizabethport, Port Johnson, Port Reading, Perth Amboy and South Amboy. The upper ports are: Port Liberty, Hoboken, Weehawken, Edgewater or Cliffside and Guttenberg. St. George is in between and sometimes a special boat rate is made. Some bituminous is shipped from Port Liberty. The ratte to the upper ports is 5c. higher than to the lower ports.

Philadelphia—Prices per gross ton f.o.b. cars at mines for line shipment and f.o.b. Port Richmond for tide shipment are as follows:

	Line— Apr. 18, 1918	Line— One Yr. Ago	Tide— Apr. 18, 1918	Tide— One Year Ago
Pea	$3.45	$2.80	$4.35	$3.70
Barley	2.15	1.50	2.40	1.75
Buckwheat	3.15	2.50	3.75	3.40
Rice	2.65	2.00	3.65	3.00
Boiler	2.45	1.80	3.55	2.90

Chicago—Steam coal prices f.o.b. mines:

Illinois Coals	Southern Illinois	Northern Illinois
Prepared sizes	$2.65—2.80	$3.35—3.50
Mine-run	2.40—2.55	3.10—3.25
Screenings	2.15—2.30	2.85—3.00

Smokeless Coals	So. Ill., Pocohontas, Pennsylvania and W. Va.	Hocking, East Kentucky and West Va. Splint
Prepared sizes	$2.60—2.85	$2.85—3.35
Mine-run	2.40—2.60	2.60—3.00
Screenings	2.10—2.55	2.35—2.75

St. Louis—Prices per net ton f.o.b. mines are as follows:

	Williamson and Franklin Counties April 18, 1918	Mt. Olive & Staunton April 18, 1918	Standard April 18, 1918
6-in. lump	$2.65-3.00	$2.65-2.80	$2.65-2.80
2-in. lump	2.65-3.00	2.65-2.80	2.25-2.50
Steam egg	2.65-2.80	2.35-2.50	2.25-2.40
Mine-run	2.45-2.60	2.45-2.60	2.45-2.60
No. 1 nut	2.65-3.00	2.65-2.80	2.65-2.80
2-in. screen	2.15-2.40	2.15-2.40	2.15-2.40
No. 5 washed	2.15-2.30	2.15-2.30	2.15-2.30

Birmingham—Current prices per net ton f.o.b. mines are as follows:

	Mine-Run	Lump & Nut	Slack and Screenings
Big Seam	$1.90	$2.15	$1.65
Pratt, Jagger, Corona	2.15	2.40	1.90
Black Creek, Cahaba	2.40	2.65	2.15

Government figures.

Individual prices are the company circulars at which coal is sold to regular customers irrespective of market conditions. Circular prices are generally the same at the same periods of the year and are fixed according to a regular schedule.